American Fisheries Society Symposium 22:43–75, 1999

Nekton Densities in Shallow Estuarine Habitats of Texas and Louisiana and the Identification of Essential Fish Habitat

THOMAS J. MINELLO
National Marine Fisheries Service
Galveston Southeast Fisheries Science Center Laboratory
4700 Avenue U, Galveston, Texas 77551, USA

Abstract.—The Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act) of 1996 requires the identification of essential fish habitat (EFH) for fishery species under federal fishery management plans (FMPs). As defined in the Magnuson-Stevens Act, EFH includes waters and substrate necessary for spawning, breeding, feeding, or growth to maturity. Without EFH, fishery species will be unable to maintain the productivity needed to support a sustainable fishery or contribute ecologically to aquatic ecosystems. The highly productive estuaries in the northern Gulf of Mexico contain many habitat types that are potentially essential for species under FMPs such as brown shrimp *Penaeus aztecus*, white shrimp *P. setiferus*, pink shrimp *P. duorarum*, gulf stone crab *Menippe adina*, red drum *Sciaenops ocellatus*, gray snapper *Lutjanus griseus*, and bluefish *Pomatomus saltatrix*; these species spend their juvenile life stages in estuarine nurseries. Estuarine habitats also may be important for prey required as forage by managed species and for other fishery species not under FMPs. My objective in this paper was to summarize information on densities of juvenile fishery species and other animals (all generally <100 mm total length) in shallow-water estuarine areas of Texas and Louisiana. I attempted to identify where these species live (delineate their habitat) and to analyze density patterns within habitats that would be useful in distinguishing EFH. My analysis was restricted to data collected with enclosure sampling techniques because these techniques have been shown to provide comparable density estimates among highly diverse shallow-water areas. Habitat types evaluated included *Spartina alterniflora* marsh edge (SAME), mixed-vegetation marsh edge, inner marsh (>5 m from open water), submerged aquatic vegetation (SAV), oyster reefs, and shallow nonvegetated bottom (SNB). Data also were categorized by season, salinity regime, estuarine system, and year of collection. Mean densities among habitat types frequently varied in relation to salinity regime, but overall, SAME was used most by brown shrimp, white shrimp, blue crab *Callinectes sapidus*, spotted seatrout *Cynoscion nebulosus*, and southern flounder *Paralichthys lethostigma*. Highest densities of pink shrimp, red drum, and sand seatrout *Cynoscion arenarius* were found in SAV. Stone crabs had highest mean densities on oyster reefs and gulf menhaden *Brevoortia patronus* on SNB. Each of the six habitat types examined ranked first or second in use by at least one of these fishery species. Thus, all of these habitat types are likely essential for some fishery species. The analysis highlighted many of the challenges confronted in determining habitat-use patterns and emphasized the need for additional systematic sampling to examine geographic variability in habitat use and to examine distribution patterns within habitats. However, in addition to analyses of intrahabitat densities, the identification of EFH requires information on functional relationships between fishery species and habitat characteristics.

Despite evidence of important ecological linkages between environmental conditions and fishery production, the management of commercial fishery resources in the United States has historically concentrated on assessing stock size and controlling fishing mortality. However, under the Magnuson-Stevens Fishery Conservation and Management Act of 1996 (Magnuson-Stevens Act), the conservation and management of fishery habitat became an important component of comprehensive fishery management programs. The Magnuson-Stevens Act directs fishery management councils and the National Marine Fisheries Service to identify essential fish habitat (EFH) for all managed fishery species and to identify adverse impacts, actions to ensure conservation and enhancement, and approaches to the restoration of EFH. Essential fish habitat is defined in the Magnuson-Stevens Act as waters and substrate necessary for spawning, breeding, feeding, or growth to maturity. Without EFH, fishery species will be unable to maintain the productivity needed to support a sustainable fishery or contribute ecologically to aquatic ecosystems (62 FR 66531) (NMFS 1997).

An organism's habitat is the place where it lives (Odum 1971; Whitaker and Levin 1975; Baltz 1990; Peters and Cross 1992; Ricklefs 1993). From this simple definition, two important concepts ensue: (1) that at any particular life stage, a species has one habitat and (2) that an organism defines its habitat by its spatial distribution. Ecologists attempt to describe the habitat of a species based on characteristics known to be ecologically meaningful; for fishery species these characteristics often include structure (e.g., vegetation type, rock outcroppings); substrate (sediment grain size, organic content); hydrodynamics (currents, tidal flooding patterns); and general hydrology (depth, temperature, salinity, turbidity). Accurately identifying the habitat for each life stage of a fishery species is a crucial first step in identifying EFH, because areas that are not habitats are not essential habitats. In addition, however, some parts of a species' habitat may not be essential for maintaining that species' productivity.

In the Gulf of Mexico, many abundant fishery species that live and spawn in coastal waters have young that migrate into estuarine nursery grounds where they grow into subadults. Habitats in estuaries are likely to contribute substantially to the productivity of these fishery species because estuarine ecosystems have some of the highest levels of primary production observed. The general link between environmental conditions in Gulf estuaries and fishery production has been recognized for some time (Gunter 1941, 1961; Hildebrand and Gunter 1953; St. Amant et al. 1962; Zein-Eldin 1963). Indeed, production of shrimp has been correlated on a large scale with the amount of coastal wetlands in the region (Turner 1977). For most species, however, specific habitats used within estuaries have not been adequately defined, and the portions of these habitats that are essential in maintaining fishery production have not been identified.

The juveniles of fishery species that use estuaries as nursery grounds are only temporary residents and transient members of estuarine communities (Deegan and Thompson 1985; Kneib 1997). These juveniles often appear to be ubiquitously distributed within estuaries, and the entire estuary might be their habitat. A habitat delineation of the entire estuary, however, does little to identify functional relationships or important interactions with habitat characteristics, and, therefore, such a delineation does little to assist us in identifying essential portions of a habitat. It is necessary to subdivide this habitat into smaller parcels (termed "intrahabitat" areas here) that have distinct features important to fishery species. We can identify these important intrahabitat areas by examining density patterns within the habitat or by examining relationships between habitat characteristics and life history functions such as growth, survival, and reproduction. Some of the most commonly examined intrahabitat areas are associated with well-recognized ecological communities within estuaries such as sea grass beds, oyster reefs, salt marshes, mangroves, tidal mudflats, and subtidal bay bottom; these community habitats are termed biotopes (Whitaker et al. 1973). The estuarine habitat of a species can also be divided into different intrahabitat areas based on other characteristics. For example, both animals and plants have different tolerances to salinities found within estuaries, and the use of the above biotopes by a fishery species can change in relation to salinity regimes (Zimmerman et al. 1990a, 1990b). Within intertidal marsh, elevation and proximity to open water also appear to affect use patterns and habitat value for some fishery species (Rozas and Reed 1993; Minello et al. 1994; Peterson and Turner 1994; Minello and Webb 1997). On nonvegetated bottom, water depth affects habitat use (Ruiz et al. 1993), and differences in sediment texture have been related to differences in shrimp (Williams 1958; Rulifson 1981) and fish (Keefe and Able 1994; Moles and Norcross 1995) distributions.

My objective in this paper is to improve our ability to delineate habitats of juvenile fishery species and other small nekton (all generally <100 mm total length or carapace width) in shallow estuarine areas of Texas and Louisiana. The density database developed for this purpose was restricted to data collected with enclosure sampling techniques because these techniques provide comparable density estimates among highly diverse biotopes (Rozas and Minello 1997). Samples were classified into six habitat types including submerged aquatic vegetation, *Spartina alterniflora* marsh edge, mixed-vegetation marsh edge, inner marsh, shallow nonvegetated bottom, and oyster reefs. Mean nekton densities were calculated for these habitat types; for fishery species, densities in different salinity regimes were also examined. On the basis of utilization patterns, I speculate on the relative importance of these intrahabitat areas and their possible designation as EFH.

Methods

Data were collected from 22 studies where enclosure samplers were used in estuarine habitats of Texas and Louisiana including published work by Zimmerman et al. (1984, 1989, 1990a, 1990b); Zimmerman and Minello (1984); Thomas et al. (1990);

Czapla (1991); Minello et al. (1991); Minello and Zimmerman (1992); Rozas and Reed (1993); Peterson and Turner (1994); Minello and Webb (1997); Rozas and Minello (in press); and unpublished study results from the Galveston Laboratory of the National Marine Fisheries Service. Over 5,000 samples were classified into the following habitat types:

- *Spartina alterniflora* marsh edge (SAME)—defined as intertidal *S. alterniflora* marsh within 5 m of open water;
- Mixed-vegetation marsh edge (MVME)—defined as above but with various other species of vegetation including *Spartina patens, Juncus roemerianus, Scirpus* spp., *Typha*, and *Distichlis spicata*;
- Inner marsh—defined as marsh more than 5 m from open water and including *S. alterniflora* or *Distichlis spicata*;
- Submerged aquatic vegetation (SAV)—including *Thalassia testudinum, Halodule wrightii, Syringodium filiforme, Halophila engelmanni,* or *Ruppia maritima*;
- Oyster reef—consisting of low intertidal areas along Confederate Reef in the Galveston Bay system of Texas;
- Shallow nonvegetated bottom (SNB)—generally restricted to water <1 m deep including creeks, ponds, shoreline, and open bay areas. Shallow nonvegetated bottom was mostly subtidal except for the shallowest areas on extreme low tides.

For each study, density data for fishes and decapod crustaceans were incorporated into the database as mean values (number per m^2) after characterizing the samples by habitat type, year, season, salinity regime, and estuarine system. Size or biomass data were not included in the database. However, I have reported mean sizes for some common fishery species based on samples in the database collected in Galveston Bay. These data and published size data by Zimmerman and Minello (1984), Thomas et al. (1990), Czapla (1991), and Rozas and Minello (in press) indicate that the vast majority of organisms represented in the database were less than 100 mm in total length (TL) or carapace width (CW). Therefore, although the database included most life stages of small resident species, only the juveniles of transient fishery species were represented.

Spring samples were those samples collected in March, April, and May; summer samples were collected in June, July, and August; fall samples were collected in September, October, and November; and winter samples were collected in December, January, and February. Estuaries were divided into salinity zones based on long-term patterns in each system (Orlando et al. 1991, 1993), and these zones were defined as oligohaline (annual mean salinity between 0.5 and 5.0 parts per thousand [ppt]), mesohaline (5–18 ppt), polyhaline (18–30 ppt), and euhaline (30–40 ppt). The different estuaries sampled along the coast were consolidated into the following systems: Lower Laguna Madre (LLM); Upper Laguna Madre (ULM); Corpus Christi Bay (CCB); Redfish, Aransas, Copano, and Mesquite Bays (AB); San Antonio Bay and Espiritu Santo Bay (SAB); Matagorda Bay (MB); Galveston Bay system (GB); Terrebonne and Timbalier Bays (TB); and Barataria Bay (BB). (See Figure 1 for the locations of these systems.)

In addition to the mean density, the standard error was included in the database for the number of samples collected in a study for each habitat type, year, season, salinity regime, and estuary combination. The number of samples (N) collected and used to calculate the mean was also recorded. In addition, a location variable was included for each mean to indicate the number of different locations sampled. The difference between replicate samples at one location and sampling two locations is one of scale. If samples were separated by a distance of approximately 2 km or more, they were considered to be from different locations. The number of locations sampled for each habitat type was 184 for SAME, 132 for SAV, 183 for SNB, 61 for MVME, 22 for inner marsh, and 2 for oyster reef. The area used for the density determination (area enclosed or sampled each time the gear was deployed) and the type of gear used to collect the samples was listed in the database. The tide level at the time of sampling also was recorded because animal densities in shallow-water areas of the estuary are affected by tidal flood stage (Rozas and Minello 1997).

No formal statistical tests were used to compare means among intrahabitat areas. The mean nekton density for any area was calculated as the mean of the means included in the database for that intrahabitat area. Use of these weighted means reduced the influence of any one study on density patterns; this approach is similar to that used in a meta-analysis. The variability, or standard error (SE), presented in this chapter also was calculated using the means as observations. This variability within habitat types was often quite high because it incorporated differences related to years, seasons, salinity regimes, and estuaries. I considered

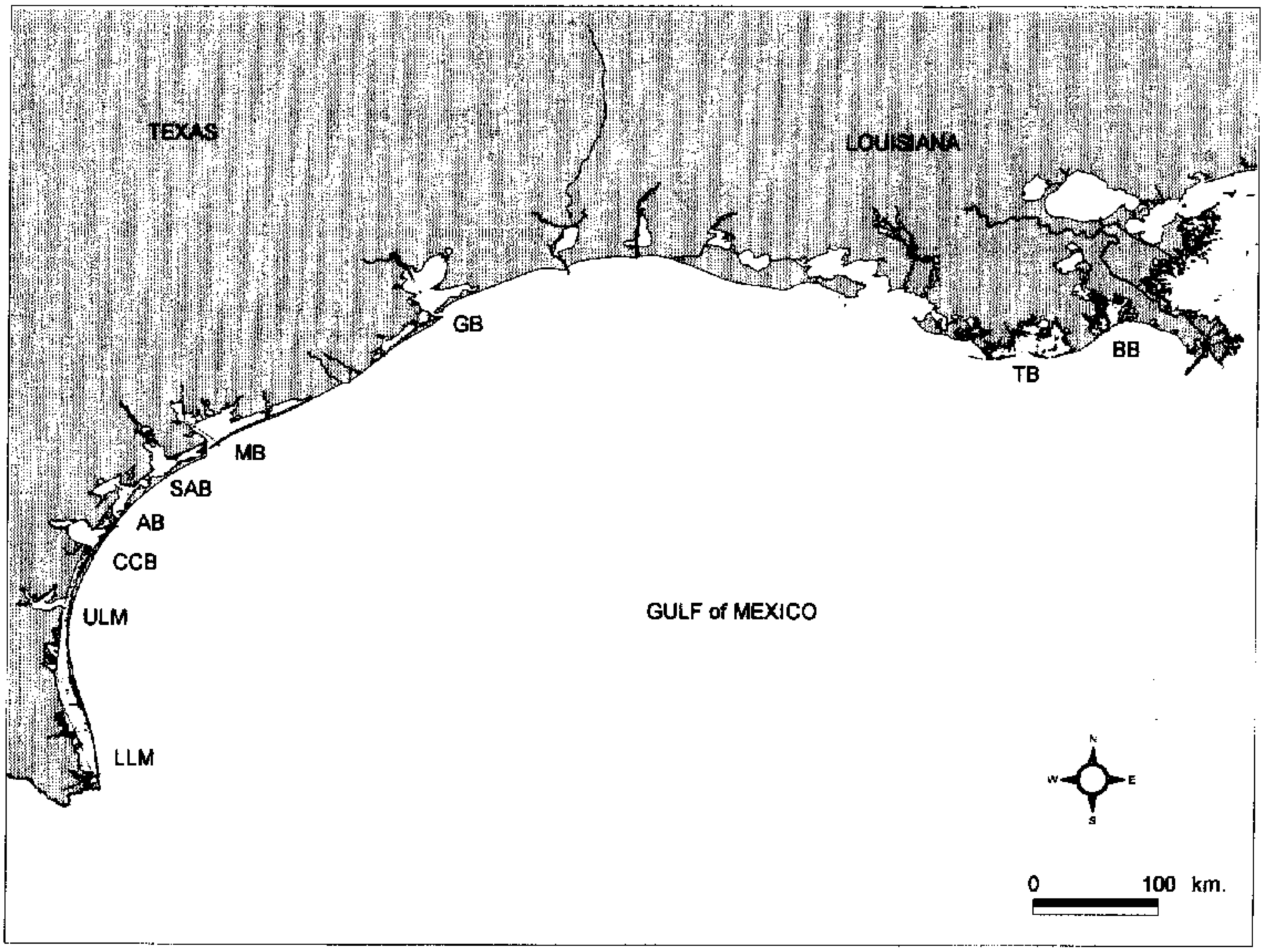

FIGURE 1.—Estuaries of Texas and Louisiana where data were collected on densities of fishery species and other nekton. Estuaries were consolidated into the following systems: Lower Laguna Madre (LLM); Upper Laguna Madre (ULM); Corpus Christi Bay (CCB); Redfish, Aransas, Copano, and Mesquite Bays (AB); San Antonio Bay and Espiritu Santo Bay (SAB); Matagorda Bay (MB); Galveston Bay system (GB); Terrebonne and Timbalier Bays (TB); and Barataria Bay (BB).

the use of a factorial analysis of variance (ANOVA) to partition this residual error, but the unbalanced nature of the data and the common occurrence of missing cells (treatment combinations with no data) made comparisons of main-effect means difficult (Milliken and Johnson 1984; Day and Quinn 1989). In addition, the data did not meet the ANOVA assumption of homogeneity in variances even following logarithmic transformation. If desired, limited statistical comparisons of means could be made using simple t-tests. The results of such tests should be quite conservative for the above reasons and because each mean generally represents a substantial number of samples.

Results

General Description of the Database

The database contained a total of 350 mean density values for every taxon found in each of the 5,149 samples represented. The most frequently sampled habitat types were *Spartina alterniflora* marsh edge, shallow nonvegetated bottom, and submerged aquatic vegetation (Table 1). Shallow nonvegetated bottom included creeks and ponds (samples collected within a marsh complex and surrounded by vegetation), shore (samples collected along semiprotected or exposed bay shorelines), and open water (a small number of samples collected at least 100 m from any shoreline). These nonvegetated samples were also characterized in the database on the basis of general substrate texture (mud versus sand). Submerged aquatic vegetation included four species of sea grasses and widgeongrass *Ruppia maritima*; the most frequently sampled type of SAV was shoalgrass *Halodule wrightii*. About 3% of the SAV samples were taken on areas of dredged material. The age of these beds is unknown, but they were at least five years old at the time of sampling. Mixed-vegetation marsh edge was represented by 258 samples and more than six species of marsh vegetation. Inner marsh (defined as areas more than 5 m away from open water) was vegetated by either *S. alterniflora* or *Distichlis spicata*. Oyster reefs were not well represented in the database, and data were recorded from only 16 samples (one study).

TABLE 1.—The number of mean density values and the total number of samples (in parentheses) represented in the database for each habitat type (in bold type) and each season.

Habitat type	Season				Total
	Spring	Summer	Fall	Winter	
Submerged aquatic vegetation (SAV)	**33 (469)**	**8 (192)**	**32 (367)**	**2 (60)**	**75 (1,088)**
Halodule wrightii	15 (320)	7 (184)	12 (232)	2 (60)	36 (796)
Halodule wrightii on old spoil	2 (6)	0 (0)	1 (3)	0 (0)	3 (9)
Halodule and *Ruppia*	5 (55)	0 (0)	9 (75)	0 (0)	14 (130)
Halophila engelmanni on old spoil	1 (4)	0 (0)	0 (0)	0 (0)	1 (4)
Ruppia maritima	2 (8)	1 (8)	3 (12)	0 (0)	6 (28)
Syringodium filiforme	4 (38)	0 (0)	3 (20)	0 (0)	7 (58)
Syringodium filiforme on old spoil	1 (8)	0 (0)	1 (3)	0 (0)	2 (11)
Thalassia testudinum	2 (24)	0 (0)	2 (16)	0 (0)	4 (40)
Thalassia testudinum on old spoil	1 (6)	0 (0)	1 (6)	0 (0)	2 (12)
***Spartina alterniflora* marsh edge (SAME)**	**39 (616)**	**22 (397)**	**36 (571)**	**12 (214)**	**109 (1,798)**
Mixed vegetation marsh edge (MVME)	**14 (87)**	**8 (51)**	**18 (120)**	**0 (0)**	**40 (258)**
Distichlis spicata	3 (8)	3 (21)	1 (15)	0 (0)	7 (44)
Juncus roemerianus	5 (44)	2 (9)	5 (46)	0 (0)	12 (99)
Phragmites australis	1 (1)	0 (0)	0 (0)	0 (0)	1 (1)
S. alterniflora and *Typha*	1 (4)	0 (0)	1 (4)	0 (0)	2 (8)
S. alterniflora, Typha and *Scirpus*	0 (0)	0 (0)	3 (12)	0 (0)	3 (12)
Scirpus maritimus	2 (14)	2 (13)	2 (11)	0 (0)	6 (38)
Scirpus spp.	1 (8)	1 (8)	1 (8)	0 (0)	3 (24)
Scirpus and Hyacinth	0 (0)	0 (0)	1 (4)	0 (0)	1 (4)
Scirpus and *S. alterniflora*	0 (0)	0 (0)	1 (4)	0 (0)	1 (4)
Spartina patens	1 (8)	0 (0)	3 (16)	0 (0)	4 (24)
Inner marsh	**5 (55)**	**4 (81)**	**4 (65)**	**1 (18)**	**14 (219)**
Distichlis spicata	1 (2)	1 (5)	0 (0)	0 (0)	2 (7)
S. alterniflora	4 (53)	3 (76)	4 (65)	1 (18)	12 (212)
Oyster reef	**0 (0)**	**1 (8)**	**0 (0)**	**1 (8)**	**2 (16)**
Shallow nonvegetated bottom	**36 (589)**	**24 (416)**	**41 (589)**	**9 (176)**	**110 (1,770)**
Creeks and ponds, mud	3 (52)	2 (24)	3 (52)	0 (0)	8 (128)
Open water, mud	0 (0)	1 (8)	0 (0)	1 (8)	2 (16)
Open water, sand	1 (24)	2 (24)	1 (16)	1 (24)	5 (88)
Shore, creeks, ponds, sandy mud	9 (286)	9 (237)	9 (221)	7 (144)	34 (888)
Shore, open water, muddy sand	1 (35)	0 (0)	1 (35)	0 (0)	2 (70)
Shore, mud	7 (36)	2 (18)	9 (52)	0 (0)	18 (106)
Shore, sandy mud	9 (114)	6 (78)	12 (170)	0 (0)	27 (362)
Shore, sand	5 (30)	2 (27)	6 (43)	0 (0)	13 (100)
Shore, muddy sand	1 (12)	0 (0)	0 (0)	0 (0)	1 (12)
Total	127 (1,816)	67 (1,145)	131 (1,712)	25 (476)	350 (5,149)

Most of the samples used in this analysis were collected in the spring and fall (68% of total), but the summer season was also well represented (Table 1). Few samples (9%) were collected during the winter, mainly because few organisms occur in these shallow-water estuarine areas during the cold months of the year. The distribution of sampling effort among seasons was similar for most habitat types. Samples in oyster reefs, however, were only collected in the summer and winter.

TABLE 2.—The number of mean density values and the total number of samples (in parentheses) represented in the database for each salinity regime and habitat type.

Summary habitat	Salinity regime				Total
	Euhaline	Polyhaline	Mesohaline	Oligohaline	
Submerged aquatic vegetation (SAV)	35 (434)	29 (606)	5 (20)	6 (28)	75 (1,088)
Spartina alterniflora marsh edge (SAME)	1 (4)	77 (1,484)	25 (291)	6 (19)	109 (1,798)
Mixed vegetation marsh edge (MVME)	0 (0)	5 (32)	17 (145)	18 (81)	40 (258)
Inner marsh	0 (0)	2 (20)	12 (199)	0 (0)	14 (219)
Oyster reef	0 (0)	2 (16)	0 (0)	0 (0)	2 (16)
Shallow nonvegetated bottom (SNB)	0 (0)	73 (1,402)	23 (268)	14 (100)	110 (1,770)
Total	36 (438)	188 (3,560)	82 (923)	44 (228)	350 (5,149)

The sampling effort represented in the database was concentrated in the polyhaline zone of estuaries, and 69% of the samples (54% of means) were collected in this salinity regime (Table 2). Mesohaline areas of estuaries were represented by 18% of the samples, while the remaining samples were split about evenly between euhaline and oligohaline areas. This distribution of sampling effort among salinity regimes was similar for most habitat types, with the important exception of SAV. Almost all SAV samples (96%) were collected in euhaline or polyhaline salinity regimes, and almost all samples in the euhaline salinity regime (primarily in the Laguna Madre of South Texas) were in SAV. Submerged aquatic vegetation is common in many oligohaline and tidal freshwater areas of these estuaries, but few samples (all widgeongrass) were available from these areas.

Seven estuarine systems in Texas were represented in the database (94% of samples), as well as two systems (6% of samples) from Louisiana (Figure 1; Table 3). Within Texas, most of the samples were collected in the Galveston Bay system (74%). The south Texas coast is relatively arid, and most of the estuaries in this region have large euhaline zones; samples from the Laguna Madre and Corpus Christi

TABLE 3.—The number of mean density values and the total number of samples (in parentheses) represented in the database for each estuary, habitat type, and salinity regime. Abbreviations for habitat types are shown in Tables 1 and 2.

Estuary	Salinity regime	Habitat type						Total
		SAV	SAME	MVME	Inner marsh	Oyster	SNB	
Lower Laguna Madre (LLM)	Euhaline	29 (264)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	29 (264)
Upper Laguna Madre (ULM)	Euhaline	6 (170)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	6 (170)
Corpus Christi Bay (CCB)	Euhaline	0 (0)	1 (4)	0 (0)	0 (0)	0 (0)	0 (0)	1 (4)
Aransas Bay Complex (AB)	Polyhaline	2 (70)	2 (60)	0 (0)	0 (0)	0 (0)	2 (70)	6 (200)
San Antonio Bay (SAB)	Polyhaline	7 (40)	6 (36)	1 (4)	0 (0)	0 (0)	7 (40)	21 (120)
	Mesohaline	5 (20)	6 (24)	1 (4)	0 (0)	0 (0)	7 (28)	19 (76)
	Oligohaline	3 (12)	3 (12)	5 (20)	0 (0)	0 (0)	7 (32)	18 (76)
Matagorda Bay,	Polyhaline	0 (0)	6 (50)	2 (8)	0 (0)	0 (0)	5 (58)	13 (116)
mainly Lavaca (MB)	Mesohaline	0 (0)	3 (9)	8 (63)	0 (0)	0 (0)	6 (76)	17 (148)
	Oligohaline	0 (0)	2 (3)	10 (37)	0 (0)	0 (0)	3 (40)	15 (80)
Galveston Bay (GB)	Polyhaline	20 (496)	62 (1,328)	2 (20)	2 (20)	2 (16)	58 (1,224)	146 (3,104)
	Mesohaline	0 (0)	9 (192)	5 (40)	3 (24)	0 (0)	10 (164)	27 (420)
	Oligohaline	3 (16)	1 (4)	3 (24)	0 (0)	0 (0)	4 (28)	11 (72)
Terrebonne and Timbalier Bays (TB)	Mesohaline	0 (0)	7 (66)	3 (38)	9 (175)	0 (0)	0 (0)	19 (279)
Barataria Bay (BB)	Polyhaline	0 (0)	1 (10)	0 (0)	0 (0)	0 (0)	1 (10)	2 (20)
Total		75 (1,088)	109 (1,798)	40 (258)	14 (219)	2 (16)	110 (1,770)	350 (5,149)

Bay were only collected in euhaline salinity regimes and were almost exclusively from SAV. The widest salinity ranges were represented in estuaries located on the central to northern coast of Texas. Inner marsh and oyster reef samples were collected only in one or two estuarine systems.

Samples in the database were collected between the years 1982 and 1997. All years except 1992 were represented, and the distribution of samples among years was relatively even. The majority of samples (84%) in the database were collected with either a 1-m^2 or 2.6-m^2 drop sampler (Zimmerman et al. 1984). Other gear used included flumes (Peterson and Turner 1994), lift nets (Rozas and Reed 1993), and throw traps. Most samples (84%) were collected when tide levels were high and intertidal vegetation was flooded.

Especially for uncommon species, the number of means recorded in these summary data are less than the possible number of means based on sampling effort. This situation reflects a problem distinguishing between zeros and missing data. I could not always determine whether the lack of a species in a list of animals meant that it was not present in the sample or that it was not identified. In this situation, I assumed that the species was not present (zero density) if that species was identified from other samples in the study. I did not include a zero for the density of a species if it was not identified in a particular study, even though this often would have been appropriate. Therefore, the count of means for the less-common species is a minimum value. Mean densities for these species would be lower than those reported here if I had included all zeros for samples from studies where the species was not identified.

General Density Patterns in Different Habitat Types

The database included over 20,000 records of mean densities for various species collected in shallow waters of these estuaries, and these means provided general information on habitats of species and on utilization patterns within habitats (Tables 4 and 5). Decapod crustaceans were the most abundant organisms (Table 4), and 54 taxa were identified including 48 species and 6 species complexes (e.g., *Callinectes* spp.). Grass shrimps in the genus *Palaemonetes* (estuarine residents) were by far the most abundant crustaceans; this genus was collected mainly within vegetated areas. The blue crab *Callinectes sapidus* and its congeners along with brown shrimp *Penaeus aztecus* [1] and white shrimp *P. setiferus* (also known as *Penaeus setiferus*) were also relatively abundant. Although rankings varied, these abundant crustaceans were generally dominant in vegetated areas and on shallow nonvegetated bottom (Table 6). The dominant crustaceans on oyster reefs were small resident crabs including the green porcelain crab *Petrolisthes armatus* and the xanthid crabs *Panopeus herbstii* and *Eurypanopeus depressus*. Crustacean species in the database under federal fishery management plans (FMPs) included brown shrimp, white shrimp, pink shrimp *P. duorarum* (also known as *Penaeus duorarum*), and gulf stone crab *Menippe adina*. There is also an active fishery for blue crab in Texas and Louisiana. Many of the other crustaceans in the database are prey for fishery species.

Compared with crustaceans, fishes were less abundant but more diverse; 86 species and 2 species complexes were identified in samples (Table 5). On the basis of mean density from all samples, gulf menhaden *Brevoortia patronus* was the most abundant fish in these estuaries. This species was concentrated mainly in oligohaline salinity regimes, and mean densities were highest on shallow nonvegetated bottom and in marsh edge (Table 5). The naked goby *Gobiosoma bosc* was also abundant, and this small resident fish was ubiquitous, being a dominant species in all habitat types except inner marsh (Table 6). Inner marsh was dominated by gulf killifish *Fundulus grandis*, diamond killifish *Adinia xenica*, and the sheepshead minnow *Cyprinodon variegatus* (all estuarine residents). The pinfish *Lagodon rhomboides* was a dominant species in *Spartina alterniflora* marsh edge and in SAV, and bay anchovy *Anchoa mitchilli* was dominant on oyster reefs and shallow nonvegetated bottom. Only three fish species in the database are under federal FMPs: red drum *Sciaenops ocellatus*, gray snapper *Lutjanus griseus*, and bluefish *Pomatomus saltatrix*. However, the database included information on habitat-use patterns for other fishery species of both commercial and recreational importance in the region including gulf menhaden, southern flounder *Paralichthys lethostigma*, spotted seatrout *Cynoscion nebulosus*, and sand seatrout *Cynoscion arenarius*.

---

[1] Perez Farfante and Kensley (1997) have revised the scientific names of brown shrimp, pink shrimp, and white shrimp to *Farfantepenaeus aztecus*, *F. duorarum*, and *Litopenaeus setiferus*, respectively.

TABLE 4.—Mean densities of decapod crustaceans in different habitat types including submerged aquatic vegetation (SAV), *Spartina alterniflora* marsh edge (SAME), mixed vegetation marsh edge (MVME), inner marsh, oyster reef, and shallow nonvegetated bottom (SNB). Each mean density (animals per m²) was calculated as the mean of means in

Taxon (common name)	SAV Mean	SAV SE	SAV Ct	SAME Mean	SAME SE	SAME Ct	MVME Mean	MVME SE	MVME Ct
Crustaceans	**50.216**	**8.724**	**75**	**83.540**	**6.500**	**109**	**36.037**	**5.627**	**40**
Acetes americanus			0	0.000	0.000	3			0
Alpheus heterochaelis (bigclaw snapping shrimp)	1.599	0.483	71	0.322	0.069	86	0.004	0.003	32
Ambidexter symmetricus	0.022	0.014	14			0			0
Callianassa jamaicensis (estuarine ghost shrimp)	0.057	0.000	1	0.008	0.005	17	0.000	0.000	2
Callianassa spp.			0	0.000	0.000	1	0.000	0.000	1
Callichirus major (Carolinian ghost shrimp)			0	0.000	0.000	6	0.000	0.000	2
Callinectes ornatus (shelligs)	0.013	0.013	15	0.000	0.000	15	0.000	0.000	7
Callinectes sapidus (blue crab)	5.047	1.155	67	6.239	0.746	100	2.698	0.891	40
Callinectes similis (lesser blue crab)	0.675	0.145	58	0.096	0.065	21	0.022	0.014	9
Callinectes spp.	13.746	2.614	8	3.980	1.969	8			0
Clibanarius vittatus (thinstripe hermit)	0.112	0.030	71	0.772	0.184	92	0.020	0.010	34
Dyspanopeus texana (gulf grassflat crab)	3.600	0.876	65	0.204	0.059	62	0.397	0.284	30
Eurypanopeus abbreviatus (lobate mud crab)	0.000	0.000	7	0.032	0.020	6	0.000	0.000	3
Eurypanopeus depressus (flatback mud crab)	0.009	0.009	22	0.042	0.017	56	0.000	0.000	31
Farfantepenaeus aztecus (brown shrimp)	7.341	1.026	54	7.479	0.699	104	2.598	0.574	40
Farfantepenaeus duorarum (pink shrimp)	1.563	0.702	30	1.050	0.238	73	0.498	0.296	31
Hippolyte zostericola (zostera shrimp)	6.466	1.402	68	0.724	0.597	45	0.004	0.004	30
Latreutes fucorum (slender sargassum shrimp)			0	0.020	0.000	1			0
Latreutes parvulus (sargassum shrimp)	0.013	0.013	15	0.002	0.002	19	0.000	0.000	23
Leander tenuicornis (brown grass shrimp)	0.000	0.000	8	0.001	0.001	12			0
Libinia dubia (longnose spider crab)	0.049	0.017	44	0.010	0.004	37	0.000	0.000	23
Litopenaeus setiferus (white shrimp)	0.462	0.109	74	5.528	1.019	98	1.507	0.483	37
Macrobrachium ohione (Ohio shrimp)	0.026	0.026	15	0.024	0.014	21	0.288	0.288	7
Menippe adina (gulf stone crab)	0.007	0.004	39	0.014	0.003	77	0.001	0.001	30
Ogyrides alphaerostris (estuarine longeye shrimp)	0.006	0.006	15	0.000	0.000	19	0.000	0.000	8
Pachygrapsus gracilis (dark shore crab)			0	0.011	0.011	3			0

TABLE 4. (cont.)—the database; also shown is the standard error (SE, calculated using means as observations) and the number of means (Ct = Count) used in the calculation. Data are included from all seasons, salinity regimes, estuaries, and years.

Taxon (common name)	Inner marsh Mean	Inner marsh SE	Inner marsh Ct	Oyster reef Mean	Oyster reef SE	Oyster reef Ct	SNB Mean	SNB SE	SNB Ct	Total Mean	Total SE	Total Ct
Crustaceans	**15.725**	**5.934**	**14**	**70.596**	**34.250**	**2**	**5.452**	**0.402**	**110**	**43.642**	**3.302**	**350**
Acetes americanus			0			0	0.299	0.299	3	0.150	0.150	6
Alpheus heterochaelis (bigclaw snapping shrimp)	0.000	0.000	1	3.481	2.288	2	0.019	0.004	102	0.511	0.125	294
Ambidexter symmetricus			0			0	0.000	0.000	6	0.015	0.010	20
Callianassa jamaicensis (estuarine ghost shrimp)	0.000	0.000	2			0	0.077	0.047	18	0.040	0.022	40
Callianassa spp.	0.000	0.000	1			0	0.025	0.025	2	0.010	0.010	5
Callichirus major (Carolinian ghost shrimp)	0.000	0.000	1			0	0.013	0.008	7	0.006	0.004	16
Callinectes ornatus (shelligs)			0			0	0.000	0.000	21	0.003	0.003	58
Callinectes sapidus (blue crab)	0.526	0.123	14	0.231	0.077	2	0.902	0.099	109	3.543	0.364	332
Callinectes similis (lesser blue crab)	0.000	0.000	2			0	0.105	0.053	34	0.362	0.075	124
Callinectes spp.			0			0	1.589	0.524	8	6.438	1.522	24
Clibanarius vittatus (thinstripe hermit)	0.033	0.033	3	1.212	0.904	2	0.099	0.037	108	0.299	0.059	310
Dyspanopeus texana (gulf grassflat crab)			0	0.000	0.000	2	0.031	0.013	74	1.125	0.267	233
Eurypanopeus abbreviatus (lobate mud crab)			0			0	0.000	0.000	9	0.008	0.005	25
Eurypanopeus depressus (flatback mud crab)	0.000	0.000	1	13.577	9.731	2	0.012	0.005	68	0.170	0.131	180
Farfantepenaeus aztecus (brown shrimp)	0.452	0.240	14	0.000	0.000	2	1.879	0.190	109	4.611	0.336	323
Farfantepenaeus duorarum (pink shrimp)	0.000	0.000	1	0.019	0.019	2	0.131	0.030	86	0.674	0.133	223
Hippolyte zostericola (zostera shrimp)			0			0	0.019	0.013	60	2.333	0.528	203
Latreutes fucorum (slender sargassum shrimp)			0			0			0	0.020	0.000	1
Latreutes parvulus (sargassum shrimp)			0			0	0.000	0.000	26	0.003	0.002	83
Leander tenuicornis (brown grass shrimp)			0			0	0.000	0.000	12	0.000	0.000	32
Libinia dubia (longnose spider crab)			0	0.000	0.000	2	0.000	0.000	42	0.017	0.005	148
Litopenaeus setiferus (white shrimp)	1.601	0.891	12	0.000	0.000	2	1.242	0.248	108	2.372	0.338	331
Macrobrachium ohione (Ohio shrimp)			0			0	0.000	0.000	27	0.042	0.029	70
Menippe adina (gulf stone crab)			0	1.885	0.731	2	0.002	0.001	88	0.023	0.012	236
Ogyrides alphaerostris (estuarine longeye shrimp)	0.000	0.000	1			0	0.006	0.006	26	0.004	0.003	69
Pachygrapsus gracilis (dark shore crab)			0			0	0.000	0.000	3	0.005	0.005	6

TABLE 4.—(continued).

Taxon (common name)	SAV Mean	SAV SE	SAV Ct	SAME Mean	SAME SE	SAME Ct	MVME Mean	MVME SE	MVME Ct
Pagurus annulipes	0.008	0.007	25			0			0
Pagurus criniticornis	0.296	0.104	37			0			0
Pagurus impressus (dimpled hermit)	0.000	0.000	14			0			0
Pagurus longicarpus (longwrist hermit)	0.059	0.029	31	0.000	0.000	6			0
Pagurus pollicaris (flatclaw hermit)	0.018	0.014	25	0.000	0.000	9			0
Palaemonetes intermedius (brackish grass shrimp)	6.891	1.502	67	5.477	1.997	74	0.443	0.171	32
Palaemonetes paludosus (riverine grass shrimp)	0.846	0.688	15	2.705	1.991	15	0.000	0.000	7
Palaemonetes pugio (daggerblade grass shrimp)	11.637	4.005	67	58.753	5.070	96	25.655	4.903	40
Palaemonetes spp.	2.042	0.735	51	21.726	6.440	16	0.000	0.000	1
Palaemonetes transversus	0.006	0.006	15	0.000	0.000	15	0.000	0.000	7
Palaemonetes vulgaris (marsh grass shrimp)	4.181	2.965	65	3.229	0.837	73	0.105	0.068	34
Panopeus herbstii (Atlantic mud crab)	0.234	0.107	38	0.205	0.093	54	0.009	0.006	25
Panopeus turgidus (ridgeback mud crab)	0.304	0.117	65	0.026	0.015	54	0.000	0.000	30
Petrolisthes armatus (green porcelain crab)	0.015	0.012	24	0.071	0.019	29	0.000	0.000	3
Petrolisthes galathinus (banded porcelain crab)			0	0.027	0.023	33	0.003	0.003	20
Pinnixa chaetopterana (tube pea crab)	0.004	0.003	42	0.002	0.001	35	0.000	0.000	10
Pinnixa cristata			0	0.000	0.000	18			0
Pinnixa lunzi (Lunz pea crab)	0.010	0.007	17			0			0
Pinnixa retinens	0.003	0.003	35	0.000	0.000	15	0.000	0.000	7
Pinnixa spp.	0.000	0.000	8	0.000	0.000	1	0.000	0.000	1
Pinnotheres maculatus (squatter pea crab)			0	0.002	0.002	7			0
Rhithropanopeus harrisii (Harris mud crab)	0.460	0.145	44	0.723	0.193	60	0.220	0.094	36
Sesarma cinereum (squareback marsh crab)	0.000	0.000	22	0.314	0.198	61	0.062	0.036	34
Sesarma reticulatum (heavy marsh crab)	0.000	0.000	27	0.301	0.174	88	1.310	0.838	37
Sesarma spp.			0	0.120	0.097	5	2.850	2.850	2
Tozeuma carolinense (arrow shrimp)	1.641	0.474	70	0.398	0.389	58	0.003	0.003	30
Trachypenaeus constrictus (roughneck shrimp)			0	0.001	0.001	10			0
Uca spp.	0.000	0.000	26	0.476	0.209	150	0.351	0.163	99

TABLE 4.—(continued).

Taxon (common name)	Inner marsh Mean	Inner marsh SE	Inner marsh Ct	Oyster reef Mean	Oyster reef SE	Oyster reef Ct	SNB Mean	SNB SE	SNB Ct	Total Mean	Total SE	Total Ct
Pagurus annulipes			0			0			0	0.008	0.007	25
Pagurus criniticornis			0			0			0	0.296	0.104	37
Pagurus impressus (dimpled hermit)			0			0	0.028	0.028	6	0.008	0.008	20
Pagurus longicarpus (longwrist hermit)			0			0	0.038	0.030	11	0.047	0.020	48
Pagurus pollicaris (flatclaw hermit)			0	0.019	0.019	2	0.003	0.002	10	0.011	0.008	46
Palaemonetes intermedius (brackish grass shrimp)	0.250	0.050	2	0.000	0.000	2	0.034	0.013	83	3.415	0.713	260
Palaemonetes paludosus (riverine grass shrimp)			0			0	0.000	0.000	21	0.918	0.551	58
Palaemonetes pugio (daggerblade grass shrimp)	10.441	4.002	10	0.500	0.192	2	0.933	0.213	109	23.621	2.255	324
Palaemonetes spp.	0.685	0.199	5			0	0.129	0.062	18	5.028	1.432	91
Palaemonetes transversus			0			0	0.000	0.000	21	0.002	0.002	58
Palaemonetes vulgaris (marsh grass shrimp)	0.033	0.033	3	0.154	0.154	2	0.016	0.007	84	1.965	0.779	261
Panopeus herbstii (Atlantic mud crab)	0.050	0.050	2	24.596	13.904	2	0.028	0.010	61	0.391	0.221	182
Panopeus turgidus (ridgeback mud crab)			0			0	0.001	0.000	68	0.098	0.036	217
Petrolisthes armatus (green porcelain crab)			0	24.731	8.923	2	0.006	0.003	30	0.592	0.420	88
Petrolisthes galathinus (banded porcelain crab)			0			0	0.000	0.000	35	0.011	0.009	88
Pinnixa chaetopterana (tube pea crab)			0			0	0.001	0.001	44	0.002	0.001	131
Pinnixa cristata			0	0.000	0.000	2	0.005	0.004	17	0.002	0.002	37
Pinnixa lunzi (Lunz pea crab)			0			0			0	0.010	0.007	17
Pinnixa retinens			0			0	0.002	0.002	21	0.002	0.001	78
Pinnixa spp.	0.000	0.000	1			0	0.025	0.025	2	0.004	0.004	13
Pinnotheres maculatus (squatter pea crab)			0			0	0.000	0.000	7	0.001	0.001	14
Rhithropanopeus harrisii (Harris mud crab)	0.000	0.000	4			0	0.155	0.030	74	0.381	0.065	218
Sesarma cinereum (squareback marsh crab)	0.067	0.033	3			0	0.007	0.007	71	0.115	0.064	191
Sesarma reticulatum (heavy marsh crab)	1.560	0.935	5			0	0.001	0.001	97	0.326	0.139	254
Sesarma spp.	1.450	1.450	2			0	0.000	0.000	7	0.575	0.387	16
Tozeuma carolinense (arrow shrimp)			0			0	0.018	0.016	77	0.594	0.176	235
Trachypenaeus constrictus (roughneck shrimp)			0			0	0.000	0.000	10	0.001	0.001	20
Uca spp.	9.157	4.060	7	0.000	0.000	2	0.002	0.001	169	0.377	0.111	453

TABLE 5.—Mean densities of fishes in different habitat types including submerged aquatic vegetation (SAV), *Spartina alterniflora* marsh edge (SAME), mixed vegetation marsh edge (MVME), inner marsh, oyster reef, and shallow nonvegetated bottom (SNB). Each mean density (animals per m²) was calculated as the mean of means in

Taxon (common name)	SAV Mean	SAV SE	SAV Ct	SAME Mean	SAME SE	SAME Ct	MVME Mean	MVME SE	MVME Ct
Fishes	**13.996**	**1.744**	**75**	**7.712**	**0.812**	**109**	**14.889**	**3.870**	**40**
Achirus lineatus (lined sole)	0.009	0.004	48	0.018	0.004	73	0.000	0.000	31
Adinia xenica (diamond killifish)	0.008	0.005	25	0.116	0.041	84	0.134	0.057	38
Anchoa hepsetus (striped anchovy)	0.159	0.080	43	0.000	0.000	4	0.000	0.000	1
Anchoa mitchilli (bay anchovy)	0.903	0.471	70	0.257	0.128	86	1.813	0.676	37
Anguilla rostrata (American eel)			0	0.000	0.000	10	0.001	0.001	20
Archosargus probatocephalus (sheepshead)	0.027	0.014	54	0.016	0.005	74	0.005	0.004	34
Arius felis (hardhead catfish)	0.010	0.006	25	0.006	0.003	49	0.003	0.002	35
Astroscopus y-graecum (southern stargazer)	0.000	0.000	8	0.000	0.000	10	0.010	0.010	20
Bairdiella chrysoura (silver perch)	0.089	0.020	66	0.125	0.049	66	0.331	0.187	36
Bathygobius soporator (frillfin goby)			0	0.006	0.006	10	0.031	0.031	20
Brevoortia patronus (gulf menhaden)	1.447	1.262	68	0.835	0.606	76	4.967	3.833	34
Chaetodipterus faber (Atlantic spadefish)	0.000	0.000	7	0.014	0.008	36	0.000	0.000	23
Chasmodes bosquianus (striped blenny)	0.006	0.006	12	0.003	0.003	15	0.000	0.000	20
Citharichthys spilopterus (bay whiff)	0.015	0.005	56	0.007	0.003	73	0.007	0.004	36
Cynoscion arenarius (sand seatrout)	0.037	0.037	6	0.005	0.003	22	0.000	0.000	21
Cynoscion nebulosus (spotted seatrout)	0.107	0.022	52	0.204	0.028	89	0.039	0.018	38
Cynoscion nothus (silver seatrout)			0	0.000	0.000	10	0.000	0.000	20
Cyprinodon variegatus (sheepshead minnow)	0.186	0.117	44	0.202	0.077	91	1.139	0.282	40
Dasyatis sabina (Atlantic stingray)	0.000	0.000	7	0.000	0.000	10	0.000	0.000	5
Dormitator maculatus (fat sleeper)	0.013	0.013	15	0.000	0.000	21	0.012	0.010	10
Dorosoma cepedianum (gizzard shad)			0	0.000	0.000	1	0.000	0.000	2
Elops saurus (ladyfish)	0.000	0.000	22	0.002	0.002	61	0.004	0.003	31

TABLE 5.(cont.)—the database; also shown is the standard error (SE, calculated using means as observations) and the number of means (Ct = count) used in the calculation. Data are included from all seasons, salinity regimes, estuaries, and years.

Taxon	Inner marsh			Oyster reef			SNB			Total		
(common name)	Mean	SE	Ct	Mean	SE	Ct	Mean	SE	Ct	Mean	SE	Ct
Fishes	**3.538**	**0.933**	**14**	**19.019**	**14.750**	**2**	**10.048**	**2.803**	**110**	**10.511**	**1.094**	**350**
Achirus lineatus (lined sole)	0.000	0.000	1	0.000	0.000	2	0.010	0.003	91	0.011	0.002	246
Adinia xenica (diamond killifish)	0.776	0.328	13			0	0.000	0.000	86	0.102	0.026	246
Anchoa hepsetus (striped anchovy)	0.000	0.000	1			0	0.019	0.014	11	0.117	0.058	60
Anchoa mitchilli (bay anchovy)	0.000	0.000	9	8.423	8.423	2	2.371	0.529	108	1.368	0.239	312
Anguilla rostrata (American eel)			0			0	0.000	0.000	14	0.001	0.001	44
Archosargus probatocephalus (sheepshead)	0.000	0.000	6	0.019	0.019	2	0.005	0.003	88	0.013	0.004	258
Arius felis (hardhead catfish)	0.000	0.000	7			0	0.013	0.004	62	0.008	0.002	178
Astroscopus y-graecum (southern stargazer)			0			0	0.000	0.000	14	0.004	0.004	52
Bairdiella chrysoura (silver perch)	0.001	0.001	7	0.000	0.000	2	0.037	0.025	82	0.113	0.031	259
Bathygobius soporator (frillfin goby)			0			0	0.000	0.000	14	0.016	0.014	44
Brevoortia patronus (gulf menhaden)	0.100	0.100	3	0.058	0.058	2	5.608	2.698	98	3.145	1.111	281
Chaetodipterus faber (Atlantic spadefish)			0			0	0.001	0.001	43	0.005	0.003	109
Chasmodes bosquianus (striped blenny)			0	0.192	0.154	2	0.000	0.000	19	0.007	0.005	68
Citharichthys spilopterus (bay whiff)	0.000	0.000	7			0	0.022	0.004	91	0.014	0.002	263
Cynoscion arenarius (sand seatrout)	0.000	0.000	1			0	0.014	0.007	33	0.010	0.004	83
Cynoscion nebulosus (spotted seatrout)	0.010	0.008	12	0.000	0.000	2	0.034	0.005	101	0.098	0.011	294
Cynoscion nothus (silver seatrout)			0			0	0.001	0.001	14	0.000	0.000	44
Cyprinodon variegatus (sheepshead minnow)	0.728	0.312	14			0	0.060	0.044	93	0.312	0.058	282
Dasyatis sabina (Atlantic stingray)	0.000	0.000	1			0	0.006	0.004	14	0.002	0.002	37
Dormitator maculatus (fat sleeper)	0.000	0.000	5			0	0.000	0.000	24	0.004	0.003	75
Dorosoma cepedianum (gizzard shad)	0.000	0.000	1			0	0.025	0.025	2	0.008	0.008	6
Elops saurus (ladyfish)	0.100	0.000	1			0	0.076	0.070	73	0.031	0.027	188

TABLE 5.—(continued).

Taxon (common name)	SAV Mean	SAV SE	SAV Ct	SAME Mean	SAME SE	SAME Ct	MVME Mean	MVME SE	MVME Ct
Etropus crossotus (fringed flounder)	0.025	0.018	6			0			0
Eucinostomus argenteus (spotfin mojarra)	0.057	0.035	65	0.006	0.002	61	0.000	0.000	33
Eucinostomus gula (silver jenny)	0.074	0.074	6	0.005	0.004	21			0
Eucinostomus lefroyi (mottled mojarra)	0.032	0.026	15	0.001	0.001	31	0.000	0.000	7
Eucinostomus melanopterus (flagfin mojarra)	0.257	0.000	1	0.023	0.016	11			0
Eucinostomus spp.	0.148	0.148	6	0.000	0.000	2	0.000	0.000	3
Evorthodus lyricus (lyre goby)	0.000	0.000	23	0.012	0.005	37	0.018	0.013	10
Fundulus grandis (gulf killifish)	0.685	0.635	31	0.396	0.096	99	0.979	0.255	40
Fundulus jenkinsi (saltmarsh topminnow)	0.000	0.000	7	0.024	0.011	13	0.034	0.020	6
Fundulus pulvereus (bayou killifish)	0.052	0.029	22	0.028	0.008	58	0.202	0.086	35
Fundulus similis (longnose killifish)	0.000	0.000	22	0.027	0.015	80	0.024	0.014	34
Gambusia affinis (western mosquitofish)	0.035	0.035	22	0.019	0.017	29	0.861	0.855	10
Gobiesox strumosus (skilletfish)	0.005	0.003	45	0.107	0.045	50	0.075	0.040	33
Gobioides broussoneti (violet goby)			0	0.011	0.009	12			0
Gobionellus boleosoma (darter goby)	1.871	0.469	68	0.914	0.311	87	0.101	0.067	39
Gobionellus oceanicus (highfin goby)	0.003	0.003	15	0.001	0.001	31	0.000	0.000	7
Gobionellus shufeldti (freshwater goby)			0	0.051	0.036	24	0.004	0.004	23
Gobiosoma bosc (naked goby)	2.015	0.614	70	2.707	0.529	94	3.993	0.868	39
Gobiosoma robustum (code goby)	1.876	0.438	68	0.063	0.049	51	0.014	0.010	30
Harengula jaguana (scaled sardine)	0.012	0.009	12			0			0
Hippocampus zosterae (dwarf seahorse)	0.078	0.020	40			0			0
Hyporhamphus unifasciatus (silverstripe halfbeak)	0.004	0.004	19	0.003	0.003	16	0.000	0.000	23
Hypsoblennius ionthas (freckled blenny)			0	0.000	0.000	1			0
Ictalurus furcatus (blue catfish)			0	0.000	0.000	10	0.003	0.003	20
Ictalurus punctatus (channel catfish)	0.000	0.000	22	0.005	0.005	21	0.000	0.000	10
Lagodon rhomboides (pinfish)	2.581	0.724	70	1.275	0.235	95	0.149	0.048	36

TABLE 5.—(continued).

Taxon (common name)	Inner marsh Mean	SE	Ct	Oyster reef Mean	SE	Ct	SNB Mean	SE	Ct	Total Mean	SE	Ct
Etropus crossotus (fringed flounder)			0			0	0.019	0.019	6	0.022	0.012	12
Eucinostomus argenteus (spotfin mojarra)	0.000	0.000	5	0.000	0.000	2	0.020	0.009	77	0.023	0.010	243
Eucinostomus gula (silver jenny)			0			0	0.002	0.002	27	0.011	0.008	54
Eucinostomus lefroyi (mottled mojarra)			0			0	0.006	0.005	37	0.008	0.005	90
Eucinostomus melanopterus (flagfin mojarra)			0			0	0.001	0.001	11	0.023	0.013	23
Eucinostomus spp.	0.000	0.000	2			0	0.021	0.012	10	0.048	0.039	23
Evorthodus lyricus (lyre goby)	0.026	0.011	5			0	0.000	0.000	39	0.007	0.002	114
Fundulus grandis (gulf killifish)	0.975	0.291	14	0.000	0.000	2	0.019	0.011	97	0.407	0.088	283
Fundulus jenkinsi (saltmarsh topminnow)	0.004	0.002	9			0	0.000	0.000	9	0.012	0.005	44
Fundulus pulvereus (bayou killifish)	0.136	0.054	11	0.000	0.000	2	0.001	0.001	65	0.059	0.017	193
Fundulus similis (longnose killifish)	0.059	0.030	6			0	0.001	0.000	82	0.015	0.006	224
Gambusia affinis (western mosquitofish)			0			0	0.000	0.000	37	0.101	0.088	98
Gobiesox strumosus (skilletfish)	0.000	0.000	2	3.442	2.750	2	0.034	0.024	66	0.087	0.035	198
Gobioides broussoneti (violet goby)			0			0	0.000	0.000	12	0.006	0.005	24
Gobionellus boleosoma (darter goby)	0.062	0.054	13	0.000	0.000	2	0.168	0.041	96	0.748	0.143	305
Gobionellus oceanicus (highfin goby)			0			0	0.000	0.000	36	0.001	0.001	89
Gobionellus shufeldti (freshwater goby)	0.008	0.005	5			0	0.025	0.024	24	0.026	0.014	76
Gobiosoma bosc (naked goby)	0.012	0.007	13	4.962	1.769	2	0.956	0.232	105	2.049	0.247	323
Gobiosoma robustum (code goby)			0			0	0.034	0.015	73	0.602	0.146	222
Harengula jaguana (scaled sardine)			0			0	0.009	0.009	12	0.011	0.006	24
Hippocampus zosterae (dwarf seahorse)			0			0			0	0.078	0.020	40
Hyporhamphus unifasciatus (silverstripe halfbeak)			0			0	0.001	0.001	23	0.002	0.001	81
Hypsoblennius ionthas (freckled blenny)			0	0.077	0.077	2	0.000	0.000	1	0.051	0.051	4
Ictalurus furcatus (blue catfish)			0			0	0.000	0.000	14	0.001	0.001	44
Ictalurus punctatus (channel catfish)			0			0	0.002	0.002	30	0.002	0.001	83
Lagodon rhomboides (pinfish)	0.000	0.000	11	0.308	0.308	2	0.134	0.031	100	1.023	0.184	314

TABLE 5.—(continued).

Taxon (common name)	SAV Mean	SAV SE	SAV Ct	SAME Mean	SAME SE	SAME Ct	MVME Mean	MVME SE	MVME Ct
Leiostomus xanthurus (spot)	0.178	0.071	68	0.062	0.023	82	0.034	0.016	37
Lepisosteus oculatus (spotted gar)			0	0.000	0.000	10	0.000	0.000	20
Lepomis cyanellus (green sunfish)			0	0.003	0.003	9			0
Lucania parva (rainwater killifish)	0.663	0.160	60	0.543	0.246	58	1.051	0.621	17
Lutjanus griseus (gray snapper)	0.003	0.003	14	0.003	0.002	8	0.000	0.000	3
Membras martinica (rough silverside)	0.000	0.000	7	0.001	0.001	25	0.007	0.007	24
Menidia beryllina (inland silverside)	0.243	0.143	52	0.600	0.270	91	0.800	0.707	37
Menticirrhus americanus (southern kingfish)			0	0.000	0.000	5			0
Menticirrhus littoralis (gulf kingfish)			0	0.000	0.000	1	0.000	0.000	1
Microgobius gulosus (clown goby)	0.077	0.047	35	0.003	0.002	58	0.007	0.007	27
Microgobius thalassinus (green goby)	0.033	0.021	59	0.005	0.002	52	0.000	0.000	12
Micropogonias undulatus (Atlantic croaker)	0.049	0.021	59	0.024	0.011	77	0.021	0.012	35
Monacanthus hispidus (planehead filefish)			0	0.010	0.010	10	0.000	0.000	20
Mugil cephalus (striped mullet)	0.011	0.006	40	0.170	0.048	93	0.199	0.049	40
Mugil curema (white mullet)	0.003	0.003	14	0.090	0.050	6	0.200	0.000	1
Myrophis punctatus (speckled worm eel)	0.155	0.057	68	0.055	0.016	78	0.048	0.021	37
Oligoplites saurus (leatherjack)	0.000	0.000	13	0.013	0.010	15	0.000	0.000	3
Ophichthus gomesi (shrimp eel)	0.062	0.021	3	0.004	0.004	8			0
Ophidion welshi (crested cusk-eel)	0.013	0.013	8			0			0
Opsanus beta (gulf toadfish)	0.083	0.021	68	0.017	0.005	70	0.008	0.006	30
Orthopristis chrysoptera (pigfish)	0.052	0.018	65	0.020	0.007	61	0.001	0.001	30
Paralichthys albigutta (gulf flounder)	0.004	0.004	8			0			0
Paralichthys lethostigma (southern flounder)	0.013	0.007	45	0.033	0.007	85	0.023	0.010	33

TABLE 5.—(continued).

Taxon (common name)	Inner marsh Mean	Inner marsh SE	Inner marsh Ct	Oyster reef Mean	Oyster reef SE	Oyster reef Ct	SNB Mean	SNB SE	SNB Ct	Total Mean	Total SE	Total Ct
Leiostomus xanthurus (spot)	0.000	0.000	5	0.000	0.000	2	0.239	0.044	105	0.146	0.024	299
Lepisosteus oculatus (spotted gar)			0			0	0.002	0.002	14	0.001	0.001	44
Lepomis cyanellus (green sunfish)			0	0.173	0.173	2	0.000	0.000	9	0.020	0.018	20
Lucania parva (rainwater killifish)	0.018	0.009	11			0	0.013	0.009	57	0.444	0.101	203
Lutjanus griseus (gray snapper)	0.000	0.000	5			0	0.000	0.000	11	0.002	0.001	41
Membras martinica (rough silverside)	0.100	0.000	1			0	0.004	0.003	32	0.005	0.003	89
Menidia beryllina (inland silverside)	0.079	0.048	12	0.788	0.788	2	0.236	0.062	103	0.418	0.125	297
Menticirrhus americanus (southern kingfish)			0			0	0.061	0.036	5	0.030	0.020	10
Menticirrhus littoralis (gulf kingfish)	0.000	0.000	1			0	0.025	0.025	2	0.010	0.010	5
Microgobius gulosus (clown goby)			0			0	0.027	0.013	70	0.026	0.010	190
Microgobius thalassinus (green goby)	0.000	0.000	1			0	0.058	0.027	62	0.031	0.011	186
Micropogonias undulatus (Atlantic croaker)	0.000	0.000	7			0	0.092	0.022	91	0.052	0.010	269
Monacanthus hispidus (planehead filefish)			0			0	0.000	0.000	14	0.002	0.002	44
Mugil cephalus (striped mullet)	0.465	0.179	14	0.077	0.077	2	0.036	0.007	105	0.118	0.020	294
Mugil curema (white mullet)	0.100	0.000	1			0	0.018	0.018	11	0.033	0.013	33
Myrophis punctatus (speckled worm eel)	0.001	0.001	8	0.019	0.019	2	0.058	0.012	99	0.077	0.015	292
Oligoplites saurus (leatherjack)			0			0	0.010	0.008	24	0.008	0.004	55
Ophichthus gomesi (shrimp eel)			0			0	0.000	0.000	8	0.011	0.006	19
Ophidion welshi (crested cusk-eel)			0			0			0	0.013	0.013	8
Opsanus beta (gulf toadfish)			0	0.096	0.096	2	0.012	0.008	85	0.033	0.007	255
Orthopristis chrysoptera (pigfish)			0			0	0.006	0.003	75	0.022	0.006	231
Paralichthys albigutta (gulf flounder)			0			0			0	0.004	0.004	8
Paralichthys lethostigma (southern flounder)	0.000	0.000	6	0.000	0.000	2	0.023	0.004	92	0.024	0.003	263

TABLE 5.—(continued).

Taxon (common name)	SAV Mean	SAV SE	SAV Ct	SAME Mean	SAME SE	SAME Ct	MVME Mean	MVME SE	MVME Ct
Poecilia latipinna (sailfin molly)	0.000	0.000	15	0.028	0.018	59	0.063	0.046	36
Pogonias cromis (black drum)	0.006	0.006	6	0.004	0.004	17	0.000	0.000	1
Pomatomus saltatrix (bluefish)			0	0.000	0.000	14			0
Pomoxis annularis (white crappie)	0.004	0.004	22	0.000	0.000	21	0.014	0.014	10
Prionotus tribulus (bighead searobin)	0.003	0.003	14	0.002	0.002	27	0.000	0.000	2
Sciaenops ocellatus (red drum)	0.096	0.054	56	0.026	0.006	82	0.010	0.006	34
Sphoeroides dorsalis (marbled puffer)			0	0.001	0.001	25			0
Sphoeroides parvus (least puffer)	0.000	0.000	30	0.009	0.004	50	0.006	0.004	32
Stellifer lanceolatus (star drum)	0.000	0.000	7	0.007	0.005	27	0.000	0.000	23
Strongylura marina (Atlantic needlefish)	0.009	0.009	23	0.021	0.010	25	0.009	0.007	27
Symphurus plagiusa (blackcheek tonguefish)	0.367	0.144	68	0.189	0.041	80	0.036	0.018	37
Syngnathus floridae (dusky pipefish)	0.007	0.005	27	0.013	0.012	33	0.003	0.002	27
Syngnathus louisianae (chain pipefish)	0.013	0.006	50	0.022	0.006	47	0.019	0.017	23
Syngnathus scovelli (gulf pipefish)	0.784	0.131	67	0.112	0.029	72	0.110	0.051	31
Syngnathus spp.	0.023	0.023	12			0			0
Synodus foetens (inshore lizardfish)	0.011	0.007	21	0.001	0.000	45	0.000	0.000	23
Trinectes maculatus (hogchoker)	0.000	0.000	7	0.000	0.000	13	0.000	0.000	3

Habitat of Fishery Species

Juvenile brown shrimp were most abundant during spring and summer, but they were also present in the fall. The mean size of brown shrimp was 28.4 mm TL (SE = 0.24), based on mean shrimp lengths in 2,858 Galveston Bay samples. Winter densities were very low, and the winter season was omitted in the analysis of distribution patterns. Brown shrimp habitat appeared to include all shallow estuarine areas examined (Table 7). This species was not recorded from oyster reefs, but only one mean value from summer (8 samples) was available for this biotope. Mean densities were highest in euhaline and polyhaline salinity regimes, but brown shrimp were also commonly found in fresher areas of estuaries. Highest mean densities were in *Spartina alterniflora* marsh edge and submerged aquatic vegetation. Mean densities of around two animals per m^2 were also recorded for mixed-vegetation marsh edge and shallow nonvegetated bottom. Inner marsh was not used extensively by brown shrimp.

Juvenile white shrimp were most abundant in the summer and fall. The mean TL of white shrimp was 31.8 mm (SE = 0.42), based on 1,524 Galveston Bay samples. This species was also found in most intrahabitat areas examined (Table 8). However, white shrimp were concentrated in the polyhaline and mesohaline regions of the estuaries. By far, the highest mean density occurred in SAME habitat. Relatively high densities of white shrimp

TABLE 5.—(continued).

Taxon (common name)	Inner marsh Mean	Inner marsh SE	Inner marsh Ct	Oyster reef Mean	Oyster reef SE	Oyster reef Ct	SNB Mean	SNB SE	SNB Ct	Total Mean	Total SE	Total Ct
Poecilia latipinna (sailfin molly)	0.209	0.124	13			0	0.000	0.000	65	0.035	0.014	188
Pogonias cromis (black drum)	0.000	0.000	1			0	0.005	0.004	24	0.005	0.003	49
Pomatomus saltatrix (bluefish)			0			0	0.010	0.007	15	0.005	0.003	29
Pomoxis annularis (white crappie)			0			0	0.000	0.000	30	0.003	0.002	83
Prionotus tribulus (bighead searobin)	0.000	0.000	1	0.019	0.019	2	0.018	0.010	34	0.009	0.004	80
Sciaenops ocellatus (red drum)	0.000	0.000	10			0	0.029	0.007	92	0.038	0.012	274
Sphoeroides dorsalis (marbled puffer)			0			0	0.004	0.002	25	0.002	0.001	50
Sphoeroides parvus (least puffer)	0.000	0.000	2			0	0.025	0.008	66	0.012	0.003	180
Stellifer lanceolatus (star drum)			0			0	0.002	0.002	33	0.003	0.002	90
Strongylura marina (Atlantic needlefish)			0			0	0.000	0.000	35	0.009	0.003	110
Symphurus plagiusa (blackcheek tonguefish)	0.000	0.000	5	0.000	0.000	2	0.201	0.033	103	0.211	0.037	295
Syngnathus floridae (dusky pipefish)			0			0	0.001	0.001	44	0.006	0.003	131
Syngnathus louisianae (chain pipefish)			0			0	0.005	0.002	57	0.014	0.003	177
Syngnathus scovelli (gulf pipefish)	0.000	0.000	1	0.000	0.000	2	0.016	0.005	90	0.250	0.040	263
Syngnathus spp.			0			0			0	0.023	0.023	12
Synodus foetens (inshore lizardfish)			0			0	0.009	0.004	58	0.005	0.002	147
Trinectes maculatus (hogchoker)			0			0	0.003	0.002	16	0.001	0.001	39

were also collected in inner marsh, SNB, and MVME. Low mean densities were recorded for SAV, and no white shrimp were found on oyster reef.

Juvenile pink shrimp (mean TL = 19.8 mm, SE = 0.48, based on 442 Galveston Bay samples) were present mainly in the summer and fall, and this species was generally less abundant than either brown shrimp or white shrimp. Pink shrimp habitat also appeared to be more restricted than the other commercially important shrimps (Table 9). Densities were low in oligohaline areas, and no pink shrimp were found in inner marsh or on oyster reefs. Mean pink shrimp densities were highest in the polyhaline salinity regime and in SAV and marsh edge.

In recording data on the gulf stone crab, I assumed that all specimens in Texas and Louisiana were *Menippe adina*, although some crabs were reported as its congener *M. mercenaria* (the eastern Gulf species). Both juvenile and adult gulf stone crabs inhabit these estuaries, but juveniles were dominant in the samples. The mean carapace width (CW) was 26.7 mm (SE = 3.49), based on 40 Galveston Bay samples; the largest specimen was 88 mm CW. This species was found almost exclusively on oyster reefs (Table 4). The limited sampling in this biotope prevented an analysis of seasonality or an examination of distribution patterns in relation to salinity; samples

TABLE 6.—Dominant taxa collected in different estuarine habitat types. For each habitat type, the 10 most abundant decapod crustaceans and fishes are listed in rank order based on mean densities.

Rank	Submerged aquatic vegetation	*Spartina alterniflora* edge marsh	Mixed vegetation edge marsh	Inner marsh	Oyster reef	Shallow non-vegetated bottom
			Decapod Crustaceans			
1	*Callinectes* spp.	*Palaemonetes pugio*	*Palaemonetes pugio*	*Uca* spp.	*Petrolisthes armatus*	*Callinectes* spp.
2	*Palaemonetes* spp.	*Palaemonetes* spp.	*Sesarma* spp.	*Palaemonetes pugio*	*Panopeus herbstii*	*Farfantepenaeus aztecus*
3	*Palaemonetes pugio*	*Farfantepenaeus aztecus*	*Callinectes sapidus*	*Sesarma* spp.	*Eurypanopeus depressus*	*Litopenaeus setiferus*
4	*Farfantepenaeus aztecus*	*Callinectes sapidus*	*Farfantepenaeus aztecus*	*Litopenaeus setiferus*	*Alpheus heterochaelis*	*Palaemonetes pugio*
5	*Palaemonetes intermedius*	*Callinectes* spp.	*Litopenaeus setiferus*	*Palaemonetes* spp.	*Menippe adina*	*Callinectes sapidus*
6	*Hippolyte zostericola*	*Litopenaeus setiferus*	*Uca* spp.	*Callinectes sapidus*	*Clibanarius vittatus*	*Palaemonetes* spp.
7	*Callinectes sapidus*	*Palaemonetes intermedius*	*Farfantepenaeus duorarum*	*Farfantepenaeus aztecus*	*Palaemonetes pugio*	*Acetes americanus*
8	*Palaemonetes vulgaris*	*Uca* spp.	*Palaemonetes intermedius*	*Palaemonetes intermedius*	*Callinectes sapidus*	*Rhithropanopeus harrisii*
9	*Dyspanopeus texana*	*Palaemonetes vulgaris*	*Dyspanopeus texana*	*Panopeus herbstii*	*Palaemonetes vulgaris*	*Farfantepenaeus duorarum*
10	*Tozeuma carolinense*	*Palaemonetes paludosus*	*Macrobrachium ohione*	*Clibanarius vittatus*	*Pagurus pollicaris*	*Callinectes similis*
			Fishes			
1	*Lagodon rhomboides*	*Gobiosoma bosc*	*Brevoortia patronus*	*Fundulus grandis*	*Anchoa mitchilli*	*Brevoortia patronus*
2	*Gobiosoma bosc*	*Lagodon rhomboides*	*Gobiosoma bosc*	*Adinia xenica*	*Gobiosoma bosc*	*Anchoa mitchilli*
3	*Gobiosoma robustum*	*Gobionellus boleosoma*	*Anchoa mitchilli*	*Cyprinodon variegatus*	*Gobiesox strumosus*	*Gobiosoma bosc*
4	*Gobionellus boleosoma*	*Brevoortia patronus*	*Cyprinodon variegatus*	*Mugil cephalus*	*Menidia beryllina*	*Leiostomus xanthurus*
5	*Brevoortia patronus*	*Menidia beryllina*	*Lucania parva*	*Poecilia latipinna*	*Pomatomus saltatrix*	*Menidia beryllina*
6	*Anchoa mitchilli*	*Lucania parva*	*Fundulus grandis*	*Fundulus pulvereus*	*Lepomis cyanellus*	*Symphurus plagiusa*
7	*Syngnathus scovelli*	*Fundulus grandis*	*Gambusia affinis*	*Brevoortia patronus*	*Lagodon rhomboides*	*Gobionellus boleosoma*
8	*Fundulus grandis*	*Anchoa mitchilli*	*Menidia beryllina*	*Mugil curema*	*Opsanus beta*	*Lagodon rhomboides*
9	*Lucania parva*	*Cynoscion nebulosus*	*Bairdiella chrysoura*	*Membras martinica*	*Chasmodes bosquianus*	*Micropogonias undulatus*
10	*Symphurus plagiusa*	*Cyprinodon variegatus*	*Fundulus pulvereus*	*Elops saurus*	*Mugil cephalus*	*Elops saurus*

on oyster reefs were available only in summer and winter in the polyhaline salinity regime of Galveston Bay. Densities presented here may be underestimated due to inadequate sampling; Valentine et al. (1994) reported that stone crabs found near edges of sea grass beds burrowed as deep as 1.25 m into the substrate.

Blue crabs also inhabit estuaries as juveniles and adults. Although specimens as large as 128 mm CW were collected, most blue crabs were small juveniles (mean CW = 16.3 mm, SE = 0.30, based on 1,432 Galveston Bay samples). These juveniles were present in every estuarine area sampled (Table 10); they were most abundant in fall but were found throughout the year. Mean densities of blue crabs were lowest in the euhaline salinity regime (mainly SAV habitat of South Texas). The highest mean densities were found in polyhaline and mesohaline SAV and SAME. Mixed-vegetation marsh edge also appeared to support relatively high densities of this species, while inner marsh, SNB, and oyster reefs had relatively low mean densities.

TABLE 7.—Density (per m²) of brown shrimp *Farfantepenaeus aztecus* in different intrahabitat areas characterized by habitat type and salinity regime. The mean densities and standard errors (SE) were calculated using means in the database as the observations. The count represents the number of means in each calculation. Only data from spring, summer, and fall are included.

Habitat type	Statistic	Salinity regime: Euhaline	Polyhaline	Mesohaline	Oligohaline	Total
Submerged aquatic vegetation	Mean	5.68	11.03	5.71	0.08	7.20
	SE	0.96	1.94	2.93	0.08	1.02
	Count	20	21	5	6	52
Spartina alterniflora marsh edge	Mean	8.56	10.44	4.02	3.43	8.31
	SE	0.00	0.94	0.79	1.43	0.74
	Count	1	62	24	6	93
Mixed vegetation marsh edge	Mean		3.94	3.42	1.45	2.60
	SE		2.25	1.10	0.35	0.57
	Count	0	5	17	18	40
Inner marsh	Mean		2.00	0.21		0.49
	SE		1.40	0.09		0.26
	Count	0	2	11	0	13
Oyster reef	Mean		0.00			0.00
	SE		0.00			0.00
	Count	0	1	0	0	1
Shallow nonvegetated bottom	Mean		2.50	1.34	0.83	1.99
	SE		0.28	0.27	0.33	0.20
	Count	0	62	23	14	99
All habitats	Mean	5.82	6.91	2.70	1.33	4.88
	SE	0.92	0.58	0.42	0.29	0.35
	Count	21	153	80	44	298

Juvenile red drum (mean TL = 51.3 mm, SE = 7.67, based on 133 Galveston Bay samples) were abundant in the fall and also present in winter samples. This species was mainly found in polyhaline and euhaline salinity regimes (Table 11). By far, the highest mean density of red drum was found in polyhaline SAV. In contrast, no red drum were found in mesohaline or oligohaline SAV. Moderate densities were recorded in polyhaline SAME and SNB. Red drum were absent on oyster reefs and rare in inner marsh or MVME.

Gray snapper were rare in the estuarine areas examined; only four juveniles were recorded from the Galveston Bay and Terrebonne and Timbalier Bay systems. The overall mean density from Table 5 was around 16 fish per ha, but if you assumed that whenever gray snapper were not reported in a study the densities were zero (i.e., all fish specimens collected in the various studies were correctly identified and reported), this density would be around 2 fish per ha. Gray snapper were only recorded from polyhaline SAV and mesohaline SAME.

Bluefish were also rare; only five juveniles were collected from Galveston Bay, all on SNB. The overall mean density for this species in Table 5 was around 50 fish per ha, but again, if you recorded a density of zero whenever this species was not reported in a study, the mean density would be considerably lower (around 4 fish per ha). Zimmerman et al. (1989) reported a density of 0.42 bluefish per m² on oyster reefs, but this value was in error; I reviewed the original data analyzed in the study and found no record of this species in the samples.

Juvenile spotted seatrout were found in all estuaries sampled and were commonly collected in summer and fall. The mean TL for this species was 48.7 mm (SE = 1.75), based on 265 Galveston Bay samples; the largest specimen collected in these samples was 145 mm TL. Spotted seatrout were concentrated in the high-salinity regions (Table 12). The highest mean density occurred in SAME followed by SAV. There was also a high mean density in MVME when it occurred in the polyhaline salinity regime. Juvenile spotted seatrout were not found on oyster reefs and were rare in inner marsh and in all oligohaline areas.

Most southern flounder were found in the spring and summer, but the species was present in estuarine habitats throughout the year. The mean TL of southern flounder was 127.2 mm (SE = 9.06), based

TABLE 8.—Density (per m²) of white shrimp *Litopenaeus setiferus* in different intrahabitat areas characterized by habitat type and salinity regime. The mean densities and standard errors (SE) were calculated using means in the database as the observations.The count represents the number of means in each calculation. Only data from summer and fall are included.

Habitat type	Statistic	Salinity regime				
		Euhaline	Polyhaline	Mesohaline	Oligohaline	Total
Submerged aquatic vegetation	Mean	0.30	1.51	0.36	0.12	0.80
	SE	0.07	0.37	0.33	0.12	0.19
	Count	15	17	4	4	40
Spartina alterniflora marsh edge	Mean		10.31	8.66	1.22	9.41
	SE		1.77	4.02	0.61	1.60
	Count	0	39	14	3	56
Mixed vegetation marsh edge	Mean		5.00	2.04	0.34	1.60
	SE		3.82	0.94	0.16	0.61
	Count	0	3	11	12	26
Inner marsh	Mean		9.90	1.33		2.40
	SE		0.00	0.77		1.26
	Count	0	1	7	0	8
Oyster reef	Mean		0.00			0.00
	SE		0.00			0.00
	Count	0	1	0	0	1
Shallow nonvegetated bottom	Mean		2.23	2.05	0.13	1.91
	SE		0.54	0.52	0.07	0.38
	Count	0	43	15	9	67
All habitats	Mean	0.30	5.27	3.63	0.34	3.78
	SE	0.07	0.81	1.19	0.11	0.54
	Count	15	104	51	28	198

on 90 Galveston Bay samples, and the largest specimen was 395 mm TL. Southern flounder were collected in samples from 7 of the 10 estuaries in the database. The highest mean density of this species was in SAME followed by MVME, SNB, and SAV (Table 13). No southern flounder were recorded from inner marsh or oyster reef.

Sand seatrout (mean TL = 39.9 mm, SE = 3.08, based on 34 Galveston Bay samples) were found only in Galveston and Lavaca Bays, in polyhaline and mesohaline salinity regimes, and during spring, summer, and fall. The highest mean density was in SAV, and the mean density was also relatively high on SNB (Table 5).

Discussion

The essential fish habitat requirements of the Magnuson-Stevens Act represent a recognition of the importance of habitats to fishery resources, provide an opportunity to enhance protection for fish habitats, and promote awareness of the role habitat characteristics play in fishery ecology. However, accurately delineating the habitat of a fishery species (or a particular life stage) requires a detailed and comprehensive assessment of where these animals live. In addition, the linkages between habitats and fishery production are complex, and the identification of intrahabitat areas as EFH is likely to be complicated.

In developing guidelines for identifying EFH, the National Marine Fisheries Service considered different levels of information available on interactions between habitats and fishery species (62 FR 66531) (NMFS 1997). The most basic information is presence and absence or frequency-of-occurrence data on the distribution of a fishery species. These data can be used to define the geographic range of a species; they also can be used to delineate the habitat of a species (where it lives) if sampling effort is adequate. However, a more informative examination of habitat-use patterns requires the measurement of relative densities in different intrahabitat areas. In addition, the only way to make legitimate comparisons among different biotopes and across different studies using different gear types is to measure actual densities of fishery species. In this pa-

TABLE 9.—Density (per m²) of pink shrimp *Farfantepenaeus duorarum* in different intrahabitat areas characterized by habitat type and salinity regime. The mean densities and standard errors (SE) were calculated using means in the database as the observations. The count represents the number of means in each calculation. Only data from summer and fall are included.

Habitat type	Statistic	Salinity regime: Polyhaline	Mesohaline	Oligohaline	Total
Submerged aquatic vegetation	Mean	3.55	0.22	0.10	2.12
	SE	1.76	0.22	0.10	1.08
	Count	11	4	4	19
Spartina alterniflora marsh edge	Mean	1.78	2.02	0.54	1.73
	SE	0.40	1.24	0.37	0.38
	Count	31	8	3	42
Mixed vegetation marsh edge	Mean	2.37	1.06	0.16	0.74
	SE	2.37	1.00	0.11	0.43
	Count	3	6	12	21
Inner marsh	Mean	0.00			0.00
	SE	0.00			0.00
	Count	1	0	0	1
Oyster reef	Mean	0.00			0.00
	SE	0.00			0.00
	Count	1	0	0	1
Shallow nonvegetated bottom	Mean	0.24	0.17	0.01	0.19
	SE	0.07	0.08	0.01	0.04
	Count	33	11	9	53
All habitats	Mean	1.36	0.87	0.15	1.01
	SE	0.32	0.41	0.07	0.21
	Count	80	29	28	137

per, I examined density patterns in shallow-water estuarine systems of Texas and Louisiana using available data collected with quantitative enclosure sampling devices. Enclosure samplers, which include throw traps, drop samplers, lift nets, and flume weirs, have high and relatively stable catch efficiencies and provide comparable density estimates for small nekton in different estuarine biotopes (Kneib 1997; Rozas and Minello 1997).

Historically, otter trawls commonly have been used for monitoring populations of fishery species in estuaries because of their relative ease of use, large areas swept, and clean samples. The data collected with trawls, however, are generally inappropriate for comparing densities among estuarine biotopes and conducting a detailed examination of habitat-use patterns. Trawls and other towed nets have low and variable catch efficiency. This efficiency varies in relation to the species and size of target animals (Kjelson and Johnson 1978; Lyons 1986; Hartman and Herke 1987; Parsley et al. 1989; Allen et al. 1992; Millar 1992) and the method of rigging, mesh size, noise of boat, towing speed and direction, tow duration, and method of net retrieval (Kashkin and Parin 1983; Thayer et al. 1983; Carothers and Chittenden 1985; Creutzberg et al. 1987; DeAlteris et al. 1989; Millar 1992; Engas 1994; Workman et al. 1995).

Catch efficiency of towed nets varies with many habitat characteristics including:

- presence of vegetation (Miller et al. 1980; Howard and Lowe 1984; Gray and Bell 1986; Leber and Greening 1986; Orth and van Montfrans 1987);
- light (Glass and Wardle 1989; Engas 1994; Michalsen et al. 1996);
- turbidity (Nielsen 1983);
- temperature (Allen et al. 1992);
- water depth (Rogers 1985; Hartman and Herke 1987; Bishop and Khan 1991; Loneragan et al. 1995); and
- substrate type (Krieger 1993).

For species that burrow in the substrate such as penaeid shrimps and some crabs, catch efficiency of towed nets will vary with all of the environmental factors that affect burrowing. Burrowing behavior of penaeids has been shown to be affected by:

TABLE 10.—Density (per m²) of blue crab *Callinectes sapidus* in different intrahabitat areas characterized by habitat type and salinity regime. The mean densities and standard errors (SE) were calculated using means in the database as the observations. The count represents the number of means in each calculation. Data from all seasons are included.

		Salinity regime				
Habitat type	Statistic	Euhaline	Polyhaline	Mesohaline	Oligohaline	Total
Submerged aquatic vegetation	Mean	0.76	13.04	5.58	1.60	5.05
	SE	0.17	2.89	3.67	0.92	1.16
	Count	35	21	5	6	67
Spartina alterniflora marsh edge	Mean	1.63	6.08	7.20	4.79	6.24
	SE	0.00	0.51	2.58	2.81	0.75
	Count	1	68	25	6	100
Mixed vegetation marsh edge	Mean		3.23	1.94	3.27	2.70
	SE		2.10	0.91	1.72	0.89
	Count	0	5	17	18	40
Inner marsh	Mean		1.15	0.42		0.53
	SE		0.45	0.10		0.12
	Count	0	2	12	0	14
Oyster reef	Mean		0.23			0.23
	SE		0.08			0.08
	Count	0	2	0	0	2
Shallow nonvegetated bottom	Mean		0.96	0.90	0.61	0.90
	SE		0.09	0.36	0.22	0.10
	Count	0	72	23	14	109
All habitats	Mean	0.79	4.56	3.25	2.40	3.54
	SE	0.17	0.51	0.89	0.82	0.36
	Count	36	170	82	44	332

- shrimp size (Dall 1958; Hughes 1968; Kurata 1981; Kenyon et al. 1995; Primavera and Lebata 1995; Liu and Loneragan 1997);
- light (Fuss and Ogren 1966; Wickham and Minkler 1975; Bishop and Herrnkind 1976);
- moon phase (Fuss and Ogren 1966; Bishop and Herrnkind 1976);
- food availability (Dall 1958);
- dissolved oxygen (Egusa and Yamamoto 1961);
- presence of predators (Fuss and Ogren 1966);
- pressure and water depth (Hughes 1966; Wickham 1967; Vance 1992);
- salinity (Lakshmi et al. 1976);
- temperature (Fuss and Ogren 1966; Aldrich et al. 1968; Hill 1985);
- sea grass type (Kenyon et al. 1995);
- substrate type (Williams 1958; Moller and Jones 1975; Aziz and Greenwood 1982);
- weather (Fuss and Ogren 1966);
- molting (Wassenberg and Hill 1984);
- endogenous rhythms (Wickham 1967; Hughes 1968, 1969; Bishop and Herrnkind 1976); and
- ammonia concentrations (Allan and Maguire 1995).

Unless one compensates for changing gear efficiency with habitat characteristics, one can never be sure whether differences in catch are due to density patterns of a target species or to gear selectivity.

The database developed for analysis in this study combines information from 22 research projects on animal densities in estuaries of Texas and Louisiana. This type of meta-analysis can provide valuable insights into patterns of species distribution, but by necessity the analysis is general in nature. To some degree, the results are dependent upon the distribution of samples in relation to intrahabitat areas. Although a large number (5,149) of enclosure samples were included in the database, patterns of animal densities and habitat use can be influenced by the distribution of samples among estuaries, salinity regimes, seasons, and habitat types. I tried to take these sampling patterns into consideration when reporting and interpreting the data.

Perhaps the most striking pattern apparent in the data was the high density of decapod crustaceans in relation to fishes. The highest overall mean density for all species was for daggerblade grass shrimp

TABLE 11.—Density (per m^2) of red drum *Sciaenops ocellatus* in different intrahabitat areas characterized by habitat type and salinity regime. The mean densities and standard errors (SE) were calculated using means in the database as the observations. The count represents the number of means in each calculation. Only data from fall and winter are included.

Habitat type	Statistic	Salinity regime: Euhaline	Polyhaline	Mesohaline	Oligohaline	Total
Submerged aquatic vegetation	Mean	0.096	0.457	0.000	0.000	0.213
	SE	0.062	0.281	0.000	0.000	0.118
	Count	8	10	4	3	25
Spartina alterniflora marsh edge	Mean		0.057	0.010	0.032	0.043
	SE		0.018	0.007	0.032	0.013
	Count	0	25	10	3	38
Mixed vegetation marsh edge	Mean		0.000	0.000	0.012	0.006
	SE		0.000	0.000	0.012	0.006
	Count	0	2	5	8	15
Inner marsh	Mean			< 0.001		< 0.001
	SE			< 0.001		< 0.001
	Count	0	0	3	0	3
Oyster reef	Mean		0.00			0.00
	SE		0.000			0.000
	Count	0	1	0	0	1
Shallow nonvegetated bottom	Mean		0.067	0.030	0.000	0.049
	SE		0.020	0.024	0.000	0.014
	Count	0	28	8	7	43
All habitats	Mean	0.096	0.120	0.011	0.009	0.073
	SE	0.062	0.046	0.007	0.006	0.025
	Count	8	66	30	21	125

Palaemonetes pugio at 23.6 organisms per m^2; the mean density for this species in *Spartina alterniflora* marsh edge was 58.8 organisms per m^2. For fishery species (not all under federal management plans), overall mean densities per m^2 were 4.61 for brown shrimp, 3.54 for blue crab, 3.14 for gulf menhaden, 2.37 for white shrimp, 0.67 for pink shrimp, 0.15 for spot, 0.10 for spotted seatrout, 0.04 for red drum, 0.02 for gulf stone crab, and 0.02 for southern flounder. Bluefish and gray snapper (<0.01 per m^2) were reported in relatively few studies, and their actual overall densities would be considerably lower than those reported in this analysis if the fish were recorded as having zero densities (as is likely) in the other studies examined.

On the basis of mean densities in the six habitat types examined, *Spartina alterniflora* marsh edge was used most by brown shrimp, white shrimp, blue crab, spotted seatrout, and southern flounder. Pink shrimp, red drum, and sand seatrout were most abundant in submerged aquatic vegetation. Stone crab had highest mean densities on oyster reef and gulf menhaden on shallow nonvegetated bottom. Each of the six habitat types examined in my analysis ranked first or second in use by at least one fishery species (Tables 4 and 5). The data indicate, therefore, that all estuarine areas examined are likely to be essential for some fishery species.

Few other studies in Gulf of Mexico estuaries provide nekton density comparisons for two or more of the habitat types examined in my analysis. Baltz et al. (1993) showed that marsh edge was used extensively by estuarine fishes in the Barataria Bay system of Louisiana; the 15 most abundant species sampled in their study (including red drum, gulf menhaden, spot, and spotted seatrout) were concentrated at the marsh–water ecotone. In Alabama, Williams et al. (1990) reported that blue crab densities were significantly higher in sea grass than on nonvegetated bottom. Sheridan (1992) compared nekton densities among sea grass, nonvegetated bottom, and mangrove prop roots in Rookery Bay, Florida. Sheridan et al. (in press) compared sea grass and nonvegetated bottom in Florida Bay; densities of pink shrimp and blue crab were highest in sea grass. In Florida, Valentine et al. (1994) reported stone crab densities to be highest at the edge of sea grass beds (0.8–6.0 crabs per m^2).

TABLE 12.—Density (per m²) of spotted seatrout *Cynoscion nebulosus* in different intrahabitat areas characterized by habitat type and salinity regime. The mean densities and standard errors (SE) were calculated using means in the database as the observations. The count represents the number of means in each calculation. Only data from summer and fall are included.

Habitat type	Statistic	Salinity regime				Total
		Euhaline	Polyhaline	Mesohaline	Oligohaline	
Submerged aquatic vegetation	Mean	0.113	0.240	0.144	0.000	0.160
	SE	0.180	0.050	0.083	0.000	0.033
	Count	9	14	4	4	31
Spartina alterniflora marsh edge	Mean		0.415	0.181	0.000	0.333
	SE		0.045	0.059	0.000	0.038
	Count	0	36	13	3	52
Mixed vegetation marsh edge	Mean		0.288	0.040	0.000	0.051
	SE		0.167	0.020	0.000	0.026
	Count	0	3	10	12	25
Inner marsh	Mean		0.100	0.003		0.017
	SE		0.000	0.003		0.014
	Count	0	1	6	0	7
Oyster Reef	Mean		0.00			0.00
	SE		0.000			0.000
	Count	0	1	0	0	1
Shallow nonvegetated bottom	Mean		0.059	0.023	0.024	0.046
	SE		0.009	0.015	0.014	0.007
	Count	0	40	13	9	62
All habitats	Mean	0.113	0.227	0.079	0.008	0.149
	SE	0.180	0.025	0.021	0.005	0.016
	Count	9	95	46	28	178

Density patterns provide information on the intrahabitat areas used most extensively by a fishery species, but determining whether a habitat is essential for a species is more difficult. If intrahabitat areas are ranked on the basis of nekton density, there is no strong basis for deciding where to draw the line between essential and nonessential areas. However, intrahabitat areas with the highest densities are most likely to be essential for that species. An argument can be made that the entire habitat of a species is essential. This contention is supported if intrahabitat areas are essential not only for sustaining production of a fishery on the species but also for supporting the ecological contribution of the species to marine ecosystems. However, identifying every place where a species lives as EFH is not likely to enhance our ability to protect specific intrahabitat areas that are most essential in maintaining fishery productivity. Therefore, to help provide additional focus to conservation efforts, the interim final rule to implement the EFH policy also recognizes that some EFH may be identified as habitat areas of particular concern (HAPC) (NMFS 1997). These HAPC would be particularly important to the long-term productivity of a fishery species, or they would be particularly vulnerable to degradation.

In shallow estuarine areas of Texas and Louisiana, brown shrimp were concentrated in SAV and SAME (Table 7), and these intrahabitat areas are likely to be an HAPC for this species. White shrimp densities were high in most marsh habitats and nearby SNB (Table 8); thus, the entire marsh biotope appeared to be an HAPC for this species. For red drum, SAV in high-salinity areas of the bays might be HAPC, but the data available for determining habitat-use patterns for this species are still inconclusive (Table 11). For other managed fishery species that use estuarine nurseries in the Gulf of Mexico such as pink shrimp, bluefish, stone crab, and gray snapper, the data available for my analysis of habitat-use patterns are probably insufficient to make decisions on HAPC. In part, the inadequacy of available data are due to low densities caused by the geographic range of these species being centered in other areas. Data analyses from other Gulf estuaries may improve the database in this regard. For example,

TABLE 13.—Density (per m²) of southern flounder *Paralichthys lethostigma* in different intrahabitat areas characterized by habitat type and salinity regime. The mean densities and standard errors (SE) were calculated using means in the database as the observations. The count represents the number of means in each calculation. Data from all seasons are included.

Habitat type	Statistic	Salinity regime: Euhaline	Polyhaline	Mesohaline	Oligohaline	Total
Submerged aquatic vegetation	Mean	0.015	0.018	0.000	0.000	0.013
	SE	0.014	0.010	0.000	0.000	0.007
	Count	18	16	5	6	45
Spartina alterniflora marsh edge	Mean		0.028	0.055	0.000	0.033
	SE		0.005	0.027	0.000	0.007
	Count	0	59	20	6	85
Mixed vegetation marsh edge	Mean		0.048	0.023	0.017	0.023
	SE		0.048	0.018	0.010	0.010
	Count	0	4	11	18	33
Inner marsh	Mean		0.000	0.000		0.000
	SE		0.000	0.000		0.000
	Count	0	1	5	0	6
Oyster reef	Mean		0.000			0.000
	SE		0.000			0.000
	Count	0	2	0	0	2
Shallow nonvegetated bottom	Mean		0.027	0.023	0.005	0.023
	SE		0.005	0.007	0.004	0.004
	Count	0	59	19	14	92
All habitats	Mean	0.015	0.027	0.030	0.009	0.024
	SE	0.014	0.003	0.010	0.005	0.003
	Count	18	141	60	44	263

gag *Mycteroperca microlepis* were not reported in any of the studies included in my analysis, but Koenig and Coleman (1998) measured densities between 0.042 and 0.055 fish per m² in sea grass beds of St. George Sound, Florida.

For many reasons, the delineation of habitat and the identification of essential intrahabitat areas should not be based solely on the density data in this analysis. All estuarine areas available to fishery species in Texas and Louisiana have not been adequately sampled. For example, few quantitative density estimates are available for deep (>1 m water depth) areas of these bays, although Hellier (1958), Jones et al. (1963), and Jones (1965) used large enclosure samplers to estimate fish biomass in Corpus Christi Bay. Tidal freshwater regions of these estuaries also have been infrequently sampled, although Castellanos (1997) documented extensive use of these habitats by blue crabs *Callinectes sapidus* in the Atchafalaya River Delta of Louisiana. The data included in my analysis on use of oyster reefs (Zimmerman et al. 1989) were limited in scope and probably do not adequately reflect the value of this biotope to managed fishery species. On the South Atlantic coast of the United States, brown shrimp, white shrimp, pink shrimp, blue crab, red drum, gray snapper, bluefish, and gag have all have been found on oyster reefs (Wenner et al. 1996; Coen et al. 1999, this volume). In Gulf of Mexico estuaries outside Texas and Louisiana, other biotopes may be important for fishery species. For example, mangroves (Thayer et al. 1987; Sheridan 1992; Mullin 1995; Thayer and Sheridan, in press); calcium carbonate rock (Beck 1995); macroalgae beds (Herrnkind and Butler 1994); and sponge communities (Herrnkind et al. 1995) may be highly utilized in Florida estuaries.

Densities of fishery species are often centered in community habitats or biotopes, but there can be substantial variability within biotopes. In the salt marsh, for example, both the distance to the marsh–water interface and the extent of tidal inundation affect nekton density patterns (Rozas and Reed 1993; Minello et al. 1994; Peterson and Turner 1994; Minello and Webb 1997). McIvor and Rozas (1996) summarized patterns of salt-marsh use by nekton and discussed factors affecting this use. In sea grass beds, wave energy has been shown to affect use by pink shrimp (Murphey and Fonseca 1995), and the amount of edge affects use by red drum (Holt et al. 1983). Rooker (1997) and Sheridan et al. (in press) showed that nekton had different densities in *Halodule wrightii* sea grass beds compared with *Thalassia testudinum*, but Fonseca et al. (1996) found few differences in nekton densities among three species of sea grasses in Tampa Bay. Regional differences in habitat use also exist, and salt marshes of the southeastern United States appear to support much lower nekton densities than marshes on the Gulf coast (Rozas 1993; Wenner and Beatty 1993; Kneib 1997). Heck and Coen (1995) also reported regional differences in predation intensity in sea grass habitats. These patterns need to be examined with a directed sampling program.

Tidal flooding patterns also complicate the measurement of density and the identification of EFH in estuaries. The marsh surface is intertidal and only available for a portion of each tidal cycle. Densities measured in my analysis were almost all conducted at high tide when all habitat types were available for exploitation. However, fishery species using intertidal marsh at high tide must retreat into adjacent subtidal areas at low tide. In the northern Gulf of Mexico, astronomical tides are small, and meteorological events often control tidal flooding. Many salt marshes in this region are subsiding, and the marsh surface is flooded for extensive periods throughout the year (Rozas and Reed 1993). Over a 1-year period in Galveston Bay (1990–1991), the marsh edge was flooded 78.1% of the time, and inner marsh was flooded 66.3% of the time (Minello and Webb 1997). A seasonal pattern in tidal flooding is also apparent with the highest flooding durations during the spring and fall (Figure 2).

Although density patterns provide insights into the value of intrahabitat areas for fishery species, the determination of EFH probably should not be based on these distribution data alone. Information on functional relationships between habitats and fishery species is required to more accurately assess habitat value, and data on survival, growth, and reproductive success in different intrahabitat areas should be used to assess EFH. A limited amount of these data are available for federally managed fishery species that use estuaries of the northern Gulf of Mexico. Stone crabs have an affinity for structured habitats, and Beck (1995, 1997) showed that structure and shelter increased growth, survival, and fecundity for this species. Both brown shrimp and white shrimp have high densities in vegetated areas, but only brown shrimp exhibited increased growth within salt marsh vegetation compared with shallow nonvegetated bottom; white shrimp growth was

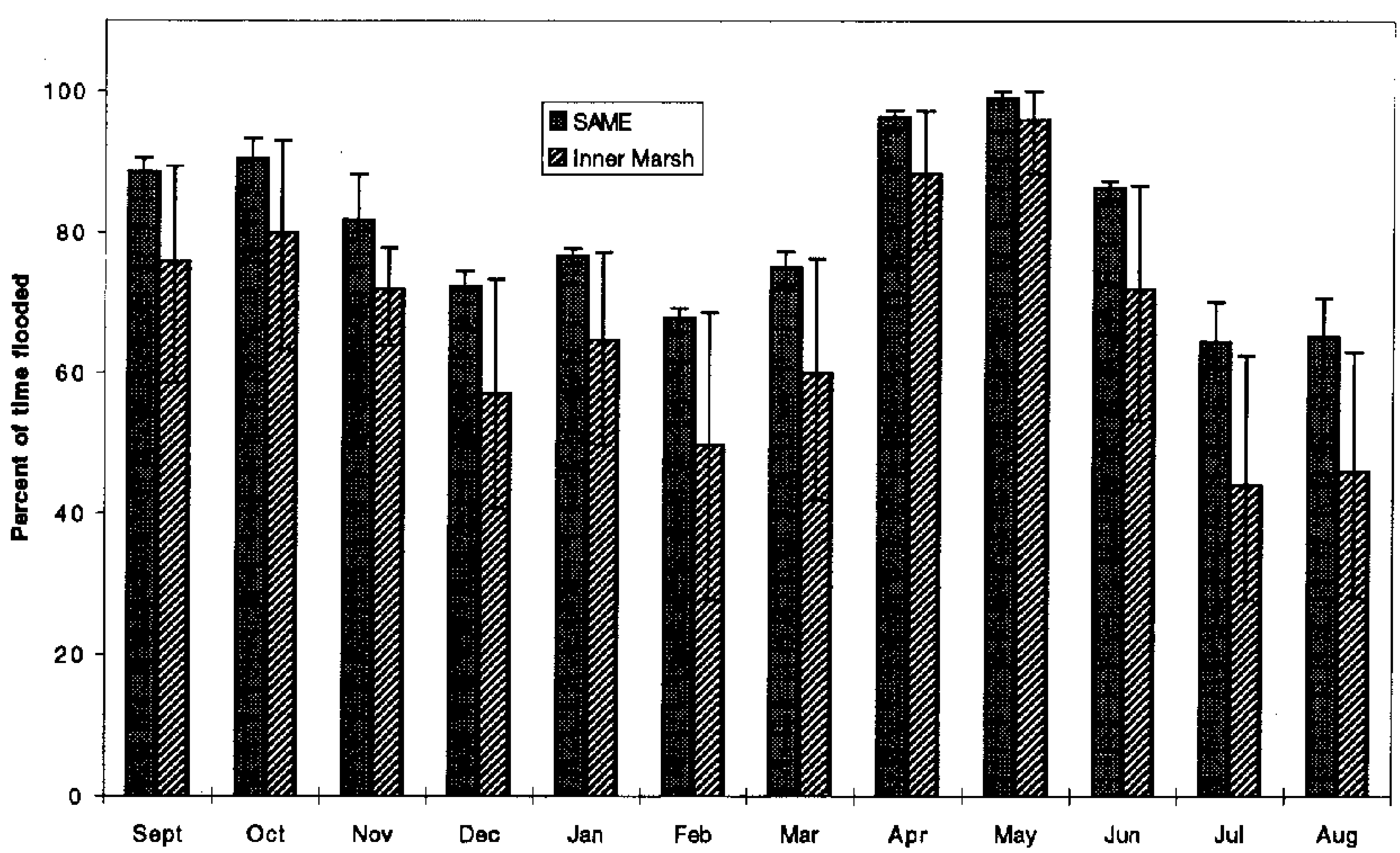

FIGURE 2.—Seasonal pattern of tidal inundation at *Spartina alterniflora* marsh edge (SAME) and inner marsh habitat types in lower Galveston Bay, Texas. Bar heights represent the mean percentage of time during each month that the habitat types were flooded in 1990–1991. Vertical lines through bars show the range for the five marshes examined. Adapted from Minello and Webb (1997).

similar between these intrahabitat areas (Minello and Zimmerman 1991). Vegetative structure also appears to reduce fish predation on juvenile brown shrimp (Minello and Zimmerman 1983; Minello et al. 1989), and survival time for tethered brown shrimp was higher in SAV and SAME compared with nonvegetated sand bottom (Minello 1993). Growth of red drum appears similar between sea grass and sand bottom (Nadeau 1991; Rooker et al. 1997), while survival of juvenile red drum was higher in SAV compared with nonvegetated bottom (Rooker et al. 1998). In estuaries of southern Florida, the structure of algae, sea grasses, and sponges has been shown to increase survival of juvenile Caribbean spiny lobsters *Panulirus argus* (Herrnkind and Butler 1986; Childress and Herrnkind 1994; Butler et al. 1995; Herrnkind et al. 1997). Similar comparative studies are needed for other habitats and other managed fishery species. Ideally, these kinds of data will be synthesized to determine relationships between productivity and the different intrahabitat areas used by fishery species.

Acknowledgments

I would like to thank Pete Sheridan, Lawrence Rozas, Ken Heck, and Roger Zimmerman for providing access to published and unpublished data sets. John Boyd helped with construction of the database, and Phil Caldwell made Figure 1. Lawrence Rozas, Donald Baltz, and two anonymous reviewers provided valuable suggestions that substantially improved the manuscript. Funding was provided by the National Oceanic and Atmospheric Administration Damage Assessment Center and the Southeast Fisheries Science Center of the National Marine Fisheries Service. This research was conducted through the Fishery Ecology Branch of the National Marine Fisheries Service Southeast Fisheries Science Center Galveston Laboratory; the assistance of everyone in the Branch was essential for the successful completion of the project.

References

Aldrich, D. V., C. E. Wood, and K. N. Baxter. 1968. An ecological interpretation of low temperature responses in *Penaeus aztecus* and *P. setiferus* postlarvae. Bulletin of Marine Science 18:61–71.

Allan, G. L., and G. B. Maguire. 1995. Effect of sediment on growth and acute ammonia toxicity for the school prawn, *Metapenaeus macleayi* (Haswell). Aquaculture 131:59–71.

Allen, D., S. Service, and M. Ogburn-Matthews. 1992. Factors influencing the collection efficiency of estuarine fishes. Transactions of the American Fisheries Society 121:234–244.

Aziz, K. A., and J. G. Greenwood. 1982. Response of juvenile *Metapenaeus bennettae* Racek & Dall, 1965 (Decapoda, Penaeidae) to sediments of differing particle size. Crustaceana 43:121–126.

Baltz, D. M. 1990. Autecology. Pages 585–607 *in* C. B. Schreck and P. B. Moyle, editors. Methods for fish biology. American Fisheries Society, Bethesda, Maryland.

Baltz, D. M., C. Rakocinski, and J. W. Fleeger. 1993. Microhabitat use by marsh-edge fishes in a Louisiana estuary. Environmental Biology of Fishes 36:109–126.

Beck, M. W. 1995. Size-specific shelter limitation in stone crabs: a test of the demographic bottleneck hypothesis. Ecology 76:968–980.

Beck, M. W. 1997. A test of the generality of the effects of shelter bottlenecks in four stone crab populations. Ecology 78:2487–2503.

Bishop, J. M., and W. F. Herrnkind. 1976. Burying and molting of pink shrimp, *Penaeus duorarum* (Crustacea: Penaeidae), under selected photoperiods of white light and U.V. light. Biological Bulletin 150:163–182.

Bishop, J. M., and M. H. Khan. 1991. Depth as a factor in abundance and size of juvenile penaeid shrimps in the absence of estuaries and marshes. Marine Biology 109:103–114.

Butler, M. J., and eight coauthors. 1995. Cascading disturbances in Florida bay, USA: cyanobacteria blooms, sponge mortality, and implications for juvenile spiny lobsters *Panulirus argus*. Marine Ecology Progress Series 129:119–125.

Carothers, P. E., and M. E. Chittenden. 1985. Relationships between trawl catch and tow duration for penaeid shrimp. Transactions of the American Fisheries Society 114:851–856.

Castellanos, D. L. 1997. Nekton use of submerged aquatic vegetation, marsh, and shallow unvegetated bottom in a Louisiana tidal freshwater ecosystem. Master's thesis. University of Southwestern Louisiana, Lafayette.

Childress, M. J., and W. F. Herrnkind. 1994. The behavior of juvenile Caribbean spiny lobster in Florida Bay: seasonality, ontogeny and sociality. Bulletin of Marine Science 54:819–827.

Coen, L. D., M. W. Luckenbach, and D. L. Breitburg. 1999. The role of oyster reefs as essential fish habitat: a review of current knowledge and some new perspectives. Pages 438–454 *in* L. R. Benaka, editor. Fish habitat: essential fish habitat, and rehabilitation. American Fisheries Society, Symposium 22, Bethesda, Maryland.

Creutzberg, F., G. C. Duineveld, and G. J. van Noort. 1987. The effect of different numbers of tickler chains on beam-trawl catches. Journal du Conseil. Conseil International pour l'Exploration de la Mer 43:159–168.

Czapla, T. E. 1991. Diets and prey selection of pinfish and southern flounder in a *Halodule wrightii* seagrass meadow. Doctoral dissertation. Texas A&M University, College Station.

Dall, W. 1958. Observations on the biology of the greentail prawn, *Metapenaeus mastersii* (Haswell) (Crustacea Decapoda: Penaeidae). Australian Journal of Marine and Freshwater Research 9:111–134.

Day, R. W., and G. P. Quinn. 1989. Comparisons of treatments after an analysis of variance in ecology. Ecological Monographs 59:433–463.

DeAlteris, J. T., C. W. Recksiek, A. Fahfouhi, and L. Xu. 1989. Comparison of the performance of two bottom-sampling trawls. Transactions of the American Fisheries Society 118:119–130.

Deegan, L. A., and B. A. Thompson. 1985. The ecology of fish communities in the Mississippi River deltaic plain. Pages 35–56 *in* A. Yanez-Arancibia, editor. Fish community ecology in estuaries and coastal lagoons: towards an ecosystem integration. UNAM Press, Mexico City.

Egusa, S., and T. Yamamoto. 1961. Studies on the respiration of the "Kuruma" prawn *Penaeus japonicus* Bate I. burrowing behavior, with special reference to environmental oxygen concentration. Bulletin of the Japanese Society of Scientific Fisheries 27:22–26.

Engas, A. 1994. The effects of trawl performance and fish behaviour on the catching efficiency of demersal sampling trawls. Pages 45–68 *in* A. Ferno and S. Olsen, editors. Marine fish behavior in capture and abundance estimation. Fishing News Books, Farnham, UK.

Fonseca, M. S., D. L. Meyer, and M. O. Hall. 1996. Development of planted seagrass beds in Tampa Bay, Florida, USA. 2. faunal components. Marine Ecology Progress Series 132:141–156.

Fuss, C. M., and L. H. Ogren. 1966. Factors affecting activity and burrowing habits of the pink shrimp, *Penaeus duorarum* Burkenroad. Biological Bulletin 130:170–191.

Glass, C. W., and C. S. Wardle. 1989. Comparison of the reactions of fish to a trawl gear at high and low light intensities. Fisheries Research 7:249–266.

Gray, C. A., and J. D. Bell. 1986. Consequences of two common techniques for sampling vagile macrofauna associated with the seagrass *Zostera capricorni*. Marine Ecology Progress Series 28:43–48.

Gunter, G. 1941. Death of fishes due to cold on the Texas coast, January, 1940. Ecology 22:203–208.

Gunter, G. 1961. Habitat of juvenile shrimp (family: Penaeidae). Ecology 42:589–600.

Hartman, R. D., and W. H. Herke. 1987. Relative selectivity of five coastal marsh sampling gears. Contributions in Marine Science 30:17–26.

Heck, K. L., and L. D. Coen. 1995. Predation and the abundance of juvenile blue crabs: a comparison of selected East and Gulf Coast (USA) studies. Bulletin of Marine Science 57:877–883.

Hellier, T. R., Jr. 1958. The drop-net quadrat, a new population sampling device. Publications of the Institute of Marine Science, University of Texas 5:165–168.

Herrnkind, W. F., and M. J. Butler. 1986. Factors regulating postlarval settlement and juvenile microhabitat use by spiny lobsters *Panulirus argus*. Marine Ecology Progress Series. 34(1-2):23–30.

Herrnkind, W. F., and M. J. Butler. 1994. Settlement of spiny lobster, *Panulirus argus* (Latreille, 1804) in Florida–pattern without predictability. Crustaceana 67:46–64.

Herrnkind, W. F., M. J. Butler, and J. H. Hunt. 1997. Can artificial habitats that mimic natural structures enhance recruitment of Caribbean spiny lobster? Fisheries 22(4):24–27.

Hildebrand, H. H., and G. Gunter. 1953. Correlation of rainfall with the Texas catch of white shrimp, *Penaeus setiferus* (Linnaeus). Transactions of the American Fisheries Society 82:151–155.

Hill, B. 1985. Effect of temperature on duration of emergence, speed of movement, and catchability of the prawn *Penaeus esculentus*. Pages 77–83 *in* P. C. Rothlisberg, B. J. Hill, and D. J. Staples, editors. Second Australian National Prawn Seminar NPS2, Cleveland, Australia.

Holt, S. A., C. L. Kitting, and C. R. Arnold. 1983. Distribution of young red drums among different sea-grass meadows. Transactions of the American Fisheries Society 112:267–271.

Howard, R. K., and K. W. Lowe. 1984. Predation by birds as a factor influencing the demography of an intertidal shrimp. Journal of Experimental Marine Biology and Ecology 74:35–52.

Hughes, D. A. 1966. Investigations of the "nursery areas" and habitat preferences of juvenile penaeid prawns in Mozambique. Journal of Applied Ecology 3:349–354.

Hughes, D. A. 1968. Factors controlling emergence of pink shrimp (*Penaeus duorarum*) from the substrate. Biological Bulletin 134:48–59.

Hughes, D. A. 1969. Evidence for the endogenous control of swimming in pink shrimp, *Penaeus duorarum*. Biological Bulletin 136:398–404.

Jones, R. S. 1965. Fish stocks from a helicopter-borne purse net sampling of Corpus Christi Bay, Texas 1962-1963. Publications of the Institute of Marine Science, University of Texas 10:68–75.

Jones, R. S., W. Ogletree, J. H. Thompson, Jr., and W. Flenniken. 1963. Helicopter borne purse net for population sampling of shallow marine bays. Publications of the Institute of Marine Science, University of Texas 9:1–6.

Kashkin, N. I., and N. V. Parin. 1983. Quantitative assessment of micronektonic fishes by nonclosing gear (a review). Biological Oceanography 2:263–287.

Keefe, M. L., and K. W. Able. 1994. Contributions of abiotic and biotic factors to settlement in summer flounder, *Paralichthys dentatus*. Copeia 2:458–465.

Kenyon, R. A., N. R. Loneragan, and J. M. Hughes. 1995. Habitat type and light affect sheltering behaviour of juvenile tiger prawns (*Penaeus esculentus* Haswell) and success rates of their fish predators. Journal of Experimental Marine Biology and Ecology 192:87–105.

Kjelson, M. A., and G. N. Johnson. 1978. Catch efficiency of a 6.1 m trawl for estuarine fish populations. Proceedings of the Southeast Association of Game and Fish Commissioners 27:653–662.

Kneib, R. T. 1997. The role of tidal marshes in the ecology of estuarine nekton. Oceanography and Marine Biology: An Annual Review 35:163–220.

Koenig, C. C., and F. C. Coleman. 1998. Absolute abundance and survival of juvenile gags in seagrass beds of the northeastern Gulf of Mexico. Transactions of the American Fisheries Society 127:44–55.

Krieger, K. J. 1993. Distribution and abundance of rockfish determined from a submersible and by bottom trawling. U.S. National Marine Fishery Service Fishery Bulletin 91:87–96.

Kurata, H. 1981. Shrimp fry releasing techniques in Japan, with special reference to the artificial tideland. Kuwait Bulletin of Marine Science 2:117–147.

Lakshmi, G. J., A. Venkataramiah, and G. Gunter. 1976. Effects of salinity and photoperiod on the burying behavior of brown shrimp *Penaeus aztecus* Ives. Aquaculture 8:327–336.

Leber, K. M., and H. S. Greening. 1986. Community studies in seagrass meadows: a comparison of two methods for sampling macroinvertebrates and fishes. U.S. National Marine Fishery Service Fishery Bulletin 84(2):443–450.

Liu, H., and N. R. Loneragan. 1997. Size and time of day affect the response of postlarvae and early juvenile grooved tiger prawns *Penaeus semisulcatus* De Haan (Decapoda:Penaeidae) to natural and artificial seagrass in the laboratory. Journal of Experimental Marine Biology and Ecology 211:263–277.

Loneragan, N. R., Y. G. Wang, R. A. Kenyon, D. J. Staples, D. J. Vance, and D. S. Heales. 1995. Estimating the efficiency of a small beam trawl for sampling tiger prawns *Penaeus esculentus* and *P. semisulcatus* in seagrass by removal experiments. Marine Ecology Progress Series 118:139–148.

Lyons, J. 1986. Capture efficiency of a beach seine for seven freshwater fishes in a north-temperate lake. North American Journal of Fisheries Management 6:288–289.

McIvor, C., and L. P. Rozas. 1996. Direct nekton use of intertidal saltmarsh habitat and linkage with adjacent habitats: a review from the southeastern United States. Pages 311–334 *in* K. F. Nordstrom and C. T. Roman, editors. Estuarine shores: evolution, environments and human alterations. Wiley, New York City.

Michalsen, K., O. R. Godo, and A. Ferno. 1996. Diel variation in the catchability of gadoids and its influence on the reliability of abundance indices. ICES Journal of Marine Science 53:389–395.

Millar, R. B. 1992. Estimating the size-selectivity of fishing gear by conditioning on the total catch. Journal of the American Statistical Association 87:962–968.

Miller, R. E., D. W. Campbell, and P. J. Lunsford. 1980. Comparison of sampling devices for the juvenile blue crab, *Callinectes sapidus*. U.S. National Marine Fishery Service Fishery Bulletin 78:196–198.

Milliken, G. A., and D. E. Johnson. 1984. Analysis of messy data. volume 1. designed experiments. Lifetime Learning Publications, Belmont, California.

Minello, T. J. 1993. Chronographic tethering: a technique for measuring prey survival time and testing predation pressure in aquatic habitats. Marine Ecology Progress Series 101:99–104.

Minello, T. J., and six coauthors. 1991. Habitat availability and utilization by benthos and nekton in Hall's Lake and West Galveston Bay. National Oceanic and Atmospheric Administration Technical Memorandum, NMFS-SEFC-275.

Minello, T. J., and J. W. Webb, Jr. 1997. Use of natural and created *Spartina alterniflora* salt marshes by fishery species and other aquatic fauna in Galveston Bay, Texas, USA. Marine Ecology Progress Series 151:165–179.

Minello, T. J., and R. J. Zimmerman. 1983. Fish predation on juvenile brown shrimp, *Penaeus aztecus* Ives: the effect of simulated *Spartina* structure on predation rates. Journal of Experimental Marine Biology and Ecology 72:211–231.

Minello, T. J., and R. J. Zimmerman. 1991. The role of estuarine habitats in regulating growth and survival of juvenile penaeid shrimp. Pages 1–16 *in* P. DeLoach, W. J. Dougherty, and M. A. Davidson, editors. Frontiers in shrimp research. Elsevier, Amsterdam.

Minello, T. J., and R. J. Zimmerman. 1992. Utilization of natural and transplanted Texas salt marshes by fish and decapod crustaceans. Marine Ecology Progress Series 90:273–285.

Minello, T. J., R. J. Zimmerman, and E. X. Martinez. 1989. Mortality of young brown shrimp *Penaeus aztecus* in estuarine nurseries. Transactions of the American Fisheries Society 118:693–708.

Minello, T. J., R. J. Zimmerman, and R. Medina. 1994. The importance of edge for natant macrofauna in a created salt marsh. Wetlands 14:184–198.

Moles, A., and B. L. Norcross. 1995. Sediment preference in juvenile Pacific flatfishes. Netherlands Journal of Sea Research 34:177–182.

Moller, T. H., and D. A. Jones. 1975. Locomotory rhythms and burrowing habits of *Penaeus semisulcatus* (de Hann) and *P. monodon* (Fabricus) (Crustacea: Penaeidae). Journal of Experimental Marine Biology and Ecology 18:61–77.

Mullin, S. J. 1995. Estuarine fish populations among red mangrove prop roots of small overwash islands. Wetlands 15:324–329.

Murphey, P. L., and M. S. Fonseca. 1995. Role of high and low energy seagrass beds as nursery areas for *Penaeus duorarum* in North Carolina. Marine Ecology Progress Series 121:91–98.

Nadeau, D. A. 1991. Relative growth rates of predatory fishes in vegetated and unvegetated habitats: field experiments with juvenile red drum, *Sciaenops ocellatus*. Master's thesis. University of South Alabama, Mobile.

Nielsen, L. 1983. Variation in the catchability of yellow perch in an otter trawl. Transactions of the American Fisheries Society 112:53–59.

NMFS (National Marine Fisheries Service). 1997. Magnuson-Stevens Act provisions: essential fish habitat: interim final rule and request for comments. Federal Register [Docket 961030300–7238–04; I.D. 120996A]: 66531–66559.

Odum, E. P. 1971. Fundamentals of ecology, 3rd edition. Saunders, Philadelphia.

Orlando, S. P., Jr., L. P. Rozas, G. H. Ward, and C. J. Klein. 1991. Analysis of salinity structure and stability for Texas estuaries. National Oceanic and Atmospheric Administration, National Ocean Service, Strategic Assessment Branch, Rockville, Maryland.

Orlando, S. P., Jr., L. P. Rozas, G. H. Ward, and C. J. Klein. 1993. Salinity characteristics of Gulf of Mexico estuaries. National Oceanic and Atmospheric Administration, Office of Ocean Resources Conservation and Assessment, Silver Spring, Maryland.

Orth, R. J., and J. van Montfrans. 1987. Utilization of a seagrass meadow and tidal marsh creek by blue crabs *Callinectes sapidus*. I. seasonal and annual variations in abundance with emphasis on postsettlement juveniles. Marine Ecology Progress Series 41:283–294.

Parsley, M. J., D. E. Palmer, and R. W. Burkhardt. 1989. Variation in capture efficiency of a beach seine for small fishes. North American Journal of Fisheries Management 9:239–244.

Perez Farfante, I., and B. Kensley. 1997. Penaeoid and sergestoid shrimps and prawns of the world: keys and diagnoses for the families and genera. Memoires du Museum National d'Histoire Naturelle, Tome 175, Paris.

Peters, D. S., and F. A. Cross. 1992. What is coastal fish habitat? Pages 17–22 *in* R. H. Stroud, editor. Stemming the tide of coastal fish habitat loss. National Coalition for Marine Conservation, Savannah, Georgia.

Peterson, G. W., and R. E. Turner. 1994. The value of salt marsh edge vs. interior as a habitat for fish and decapod crustaceans in a Louisiana tidal marsh. Estuaries 17:235–262.

Primavera, J. H., and J. Lebata. 1995. Diel activity patterns in *Metapenaeus* and *Penaeus* juveniles. Hydrobiologia 295:295–302.

Ricklefs, R. E. 1993. The economy of nature: a textbook in basic ecology, 3rd edition. Freeman, New York City.

Rogers, B. D. 1985. A small push-otter trawl for use in shallow marshes. North American Journal of Fisheries Management 5:411–413.

Rooker, J. 1997. Early life history of red drum (*Sciaenops ocellatus*) in subtropical seagrass meadows: patterns of condition, growth, and mortality. Doctoral dissertation. University of Texas, Marine Science Institute, Port Aransas.

Rooker, J. R., G. J. Holt, and S. A. Holt. 1997. Condition of larval and juvenile red drum (*Sciaenops ocellatus*) from estuarine nursery habitats. Marine Biology 127:387–394.

Rooker, J. R., G. J. Holt, and S. A. Holt. 1998. Vulnerability of newly settled red drum (*Sciaenops ocellatus*) to predatory fish: is early-life survival enhanced by seagrass meadows? Marine Biology 131:145–151.

Rozas, L. P. 1993. Nekton use of salt marshes of the Southeast region of the United States. Pages 528–537 *in* O. Magoon, W. S. Wilson, H. Converse, and L. T. Tobin, editors. Coastal Zone '93, volume 2. Proceedings of the 8th symposium on coastal and ocean management. American Society Of Civil Engineers, New York City.

Rozas, L. P., and T. J. Minello. 1997. Estimating densities of small fishes and decapod crustaceans in shallow estuarine habitats: a review of sampling design with focus on gear selection. Estuaries 20:199–213.

Rozas, L. P., and T. J. Minello. In press. Nekton use of salt marsh, seagrass, and nonvegetated habitats in a South Texas (USA) estuary. Bulletin of Marine Science.

Rozas, L. P., and D. J. Reed. 1993. Nekton use of marsh-surface habitats in Louisiana (USA) deltaic salt marshes undergoing submergence. Marine Ecology Progress Series 96:147–157.

Ruiz, G. M., A. H. Hines, and M. H. Posey. 1993. Shallow water as a refuge habitat for fish and crustaceans in nonvegetated estuaries—an example from Chesapeake Bay. Marine Ecology Progress Series 99:1–16.

Rulifson, R. A. 1981. Substrate preferences of juvenile penaeid shrimps in estuarine habitats. Contributions in Marine Science 24:35–52.

Sheridan, P., G. McMahan, G. Conley, A. Williams, and G. Thayer. In press. Nekton use of macrophyte patches following mortality of turtlegrass, *Thalassia testudinum*, in shallow waters of Florida Bay (Florida, USA). Bulletin of Marine Science 60.

Sheridan, P. F. 1992. Comparative habitat utilization by estuarine macrofauna within the mangrove ecosystem of Rookery Bay, Florida. Bulletin of Marine Science 50:21–39.

St. Amant, L. S., K. C. Corkum, and J. G. Broom. 1962. Studies on growth dynamics of the brown shrimp, *Penaeus aztecus*, in Louisiana waters. Proceedings of the Gulf and Caribbean Fishery Institute 18:1–16.

Thayer, G. W., D. R. Colby, and W. F. Hettler. 1987. Utilization of the red mangrove prop root habitat by fishes in south Florida. Marine Ecology Progress Series 35:25–38.

Thayer, G. W., D. R. Colby, M. A. Kjelson, and M. P. Weinstein. 1983. Estimates of larval-fish abundance: diurnal variation and influences of sampling gear and towing speed. Transactions of the American Fisheries Society 112:272–279.

Thayer, G. W., and P. F. Sheridan. In press. Fish, and aquatic invertebrate use of the mangrove prop root habitat in Florida: a review. *In* A. Yanez-Arancibia, and A. L. Lara-Dominguez, editors. Ecosistemas de Manglar en America Tropical: estructura, funcion, y manejo. Programa EPOMEX, Univ. Nac. Auton. Campeche, Campeche, Mexico.

Thomas, J. L., R. J. Zimmerman, and T. J. Minello. 1990. Abundance patterns of juvenile blue crabs (*Callinectes sapidus*) in nursery habitats of two Texas bays. Bulletin of Marine Science 46:115–125.

Turner, R. E. 1977. Intertidal vegetation and commercial yields of penaeid shrimp. Transactions of the American Fisheries Society 106:411–416.

Valentine, J. F., K. L. Heck, P. Harper, and M. Beck. 1994. Effects of bioturbation in controlling turtlegrass (*Thalassia testudinum* Banks *ex* Konig) abundance:

evidence from field enclosures and observations in the northern Gulf of Mexico. Journal of Experimental Marine Biology and Ecology 178:181–192.

Vance, D. J. 1992. Activity patterns of juvenile penaeid prawns in response to artificial tidal and day-night cycles: a comparison of three species. Marine Ecology Progress Series 87:215–226.

Wassenberg, T. J., and B. J. Hill. 1984. Moulting behavior of the tiger prawn *Penaeus esculentus* (Haswell). Australian Journal of Marine and Freshwater Research 35:561–571.

Wenner, E. L., and H. R. Beatty. 1993. Utilization of shallow estuarine habitats in South Carolina, USA, by postlarval and juvenile stages of *Penaeus* spp. (Decapoda, Penaeidae). Journal of Crustacean Biology 13:280–295.

Wenner, E., H. R. Beatty, and L. Coen. 1996. A method for quantitatively sampling nekton on intertidal oyster reefs. Journal of Shellfish Research 15:769–775.

Whitaker, R. H., and S. A. Levin. 1975. Introduction. Page 448 *in* R. H. Whitaker and S. A. Levin, editors. Niche; theory and application. Benchmark papers in ecology No. 3. Dowden, Hutchinson, and Ross, Stroudsburg, Pennsylvania.

Whitaker, R. H., S. A. Levin, and R. B. Root. 1973. Niche, habitat, and ecotope. American Naturalist 107:321–338.

Wickham, D. A. 1967. Observations on the activity patterns in juveniles of the pink shrimp, *Penaeus duorarum*. Bulletin of Marine Science 17:769–786.

Wickham, D. A., and F. C. Minkler. 1975. Laboratory observations on daily patterns of burrowing and locomotor activity of pink shrimp, *Penaeus duorarum*, brown shrimp, *Penaeus aztecus*, and white shrimp, *Penaeus setiferus*. Contributions in Marine Science 19:21–35.

Williams, A. B. 1958. Substrates as a factor in shrimp distribution. Limnology and Oceanography 3:283–290.

Williams, A. H., L. D. Coen, and M. S. Stoelting. 1990. Seasonal abundance, distribution, and habitat selection of juvenile *Callinectes sapidus* (Rathbun) in the northern Gulf of Mexico. Journal of Experimental Marine Biology and Ecology 137:165–183.

Workman, I. K., C. W. Taylor, and J. W. Watson. 1995. Improving pelagic fish retention in sampling trawls with a fish funnel. Scientia Marina 59:581–585.

Zein-Eldin, Z. 1963. Effect of salinity on growth of postlarval penaeid shrimp. Biological Bulletin 125:188–196.

Zimmerman, R. J., and T. J. Minello. 1984. Densities of *Penaeus aztecus*, *P. setiferus* and other natant macrofauna in a Texas salt marsh. Estuaries 7:421–433.

Zimmerman, R. J., T. J. Minello, T. J. Baumer, and M. C. Castiglione. 1989. Oyster reef as habitat for estuarine macrofauna. National Oceanic and Atmospheric Administration Technical Memorandum, NMFS-SEFC-249.

Zimmerman, R. J., T. J. Minello, M. C. Castiglione, and D. L. Smith. 1990a. The use of *Juncus* and *Spartina* marshes by fisheries species in Lavaca Bay, Texas, with reference to effects of floods. National Oceanic and Atmospheric Administration Technical Memorandum, NMFS-SEFC-251.

Zimmerman, R. J., T. J. Minello, M. C. Castiglione, and D. L. Smith. 1990b. Utilization of marsh and associated habitats along a salinity gradient in Galveston Bay. National Oceanic and Atmospheric Administration Technical Memorandum, NMFS-SEFC-250.

Zimmerman, R. J., T. J. Minello, and G. Zamora. 1984. Selection of vegetated habitat by brown shrimp, *Penaeus aztecus*, in a Galveston Bay salt marsh. U.S. National Marine Fishery Service Fishery Bulletin 82:325–336.